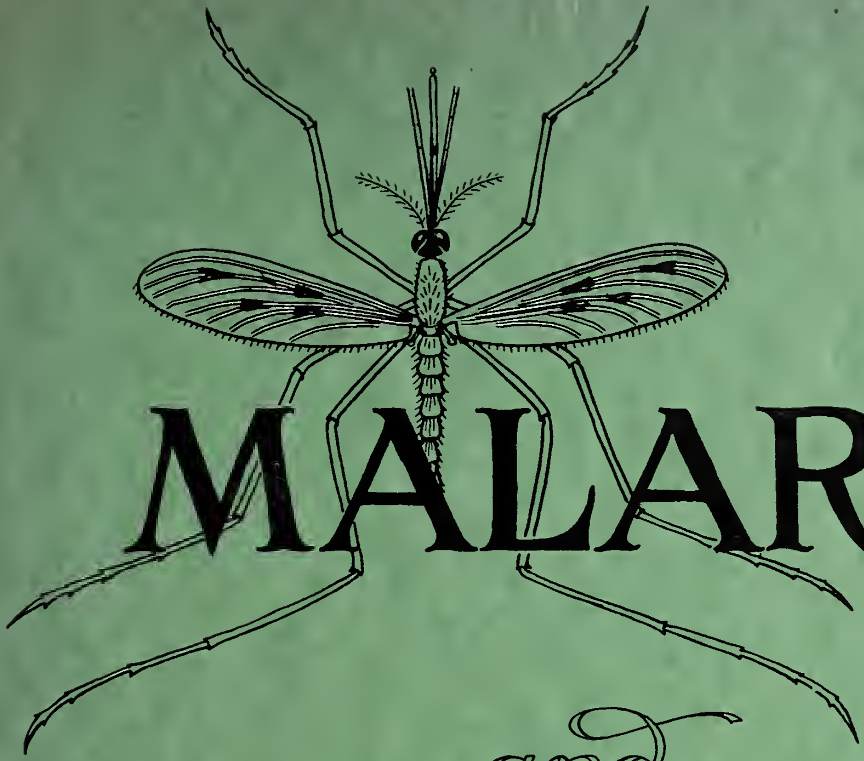

MALARIA

and

ITS CONTROL
IN THE
TENNESSEE VALLEY

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MALARIA AND ITS CONTROL IN THE TENNESSEE VALLEY

(Second Edition)

Prepared by

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FOREWORD

Intelligent community action for the control of malaria is dependent upon sound knowledge of the nature of the disease, of the manner in which it is spread, and of the ways in which it may be kept in check. The information herein presented has special reference to the Tennessee Valley, in parts of which malaria has long been a serious problem. This bulletin is addressed particularly to those who are potential leaders in a malaria education program: teachers, citizens, and students who would arm themselves with the essential facts of the disease.

This book is now in its second edition. Those using the material are requested to submit their suggestions for its improvement since in no other way can later editions be made more useful and more suitable to an educational program for malaria control in the region.

E. L. B.

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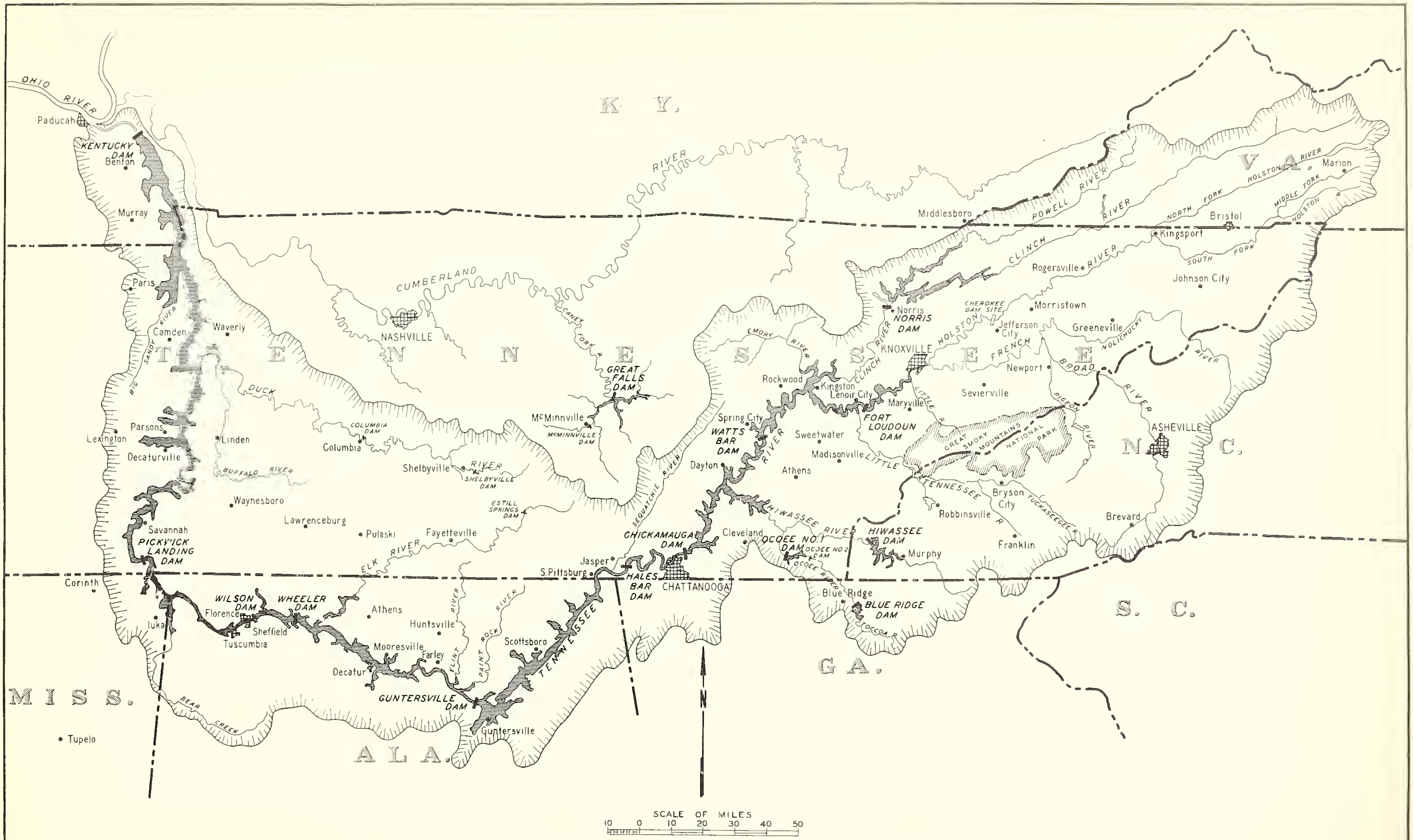


THE TENNESSEE RIVER VALLEY
FIG. I

MALARIA AND ITS CONTROL IN THE TENNESSEE VALLEY

INTRODUCTION

Malaria, long prevalent in the Tennessee Valley, remains today a serious health problem among many of the inhabitants of the region. For years it has reaped its toll in sickness, inefficiency, poor crop yield, low land values, and death. Although now its greatest existence is in the middle third of the Valley, in a zone extending from Guntersville, Alabama, to Pickwick Landing, Tennessee, where conditions remain favorable for its perpetuation, no part of the Valley is entirely free from the potential dangers of its devastating effects.

Basic to the eradication of this disease from the region is a need for widespread knowledge of its cause, spread, and control. Through tedious research and through experience, this knowledge has been accumulating over a period of years. For hundreds of years, people believed that malaria was caused by gases and foul odors which arose from swampy places. Toward the latter part of the 19th century, however, scientists discovered that the real cause of malaria was an animal parasite which depended upon both man and mosquito for its existence. Prior to this discovery, no rational action could be taken against the disease, but today there is knowledge which, if applied, would greatly diminish its prevalence.

The control of malaria is a complex problem. Although many of its manifestations are similar wherever it appears throughout the world, certain other characteristics vary with the different regions in which it is found. This means that any effective attack in a particular region must be based not only on what is known about the disease in general but also upon its peculiar characteristics in that region. Consequently, in this bulletin there will be described facts about malaria and its control with special reference to the Tennessee Valley as a region.

THE SERIOUSNESS OF MALARIA

Malaria causes much illness and, contrary to common belief, many deaths. It weakens people, making them more susceptible to other diseases; and when it occurs along with another disease, both illnesses may be prolonged. Even more serious, the combined effects may result in death, when alone neither disease would have been fatal. According to the United States census for the years 1934-39 an average of 3,294 deaths from this disease occurred annually in the United States.

At present it is impossible to obtain a true picture of the extent of malaria in a particular region. Many people suffering from the disease fail to report to a doctor, and, too, the malaria parasite may be present in a person without any outward symptoms except weakness or tiredness. Even blood examinations may fail to reveal the parasites.

Malaria is most common in rural communities, and it occurs most frequently at the time of year when crops need to be planted and harvested. Thus, it interferes with the very work which provides the principal source of income. Some people are so continuously "fagged out" by the disease that they are hardly ever able to do a good day's work. It has been said that no place is habitable by white people where malaria is prevalent. This does not mean that they cannot live where malaria is widespread, but rather that they do not thrive there.

It is very difficult to estimate in terms of money the total cost of malaria to a community. Money spent for medicine and doctors can be calculated, but it is hard to give money value to losses of time from work, damages to health, inferior crops, inability to attend school, and the like. A conservative estimate of costs of medical care and drugs alone is $2.50 per illness. Careful study has led some investigators to believe that $40.00 is a reasonable value to attach to the average cost of each infection, including the primary attack of the disease and the relapses which commonly follow. On this basis it has been estimated that from 1936 to 1938, malaria occurring in communities within one mile of the Tennessee River in North Alabama alone caused a loss exceeding $1,200,000 (Fig. 2).

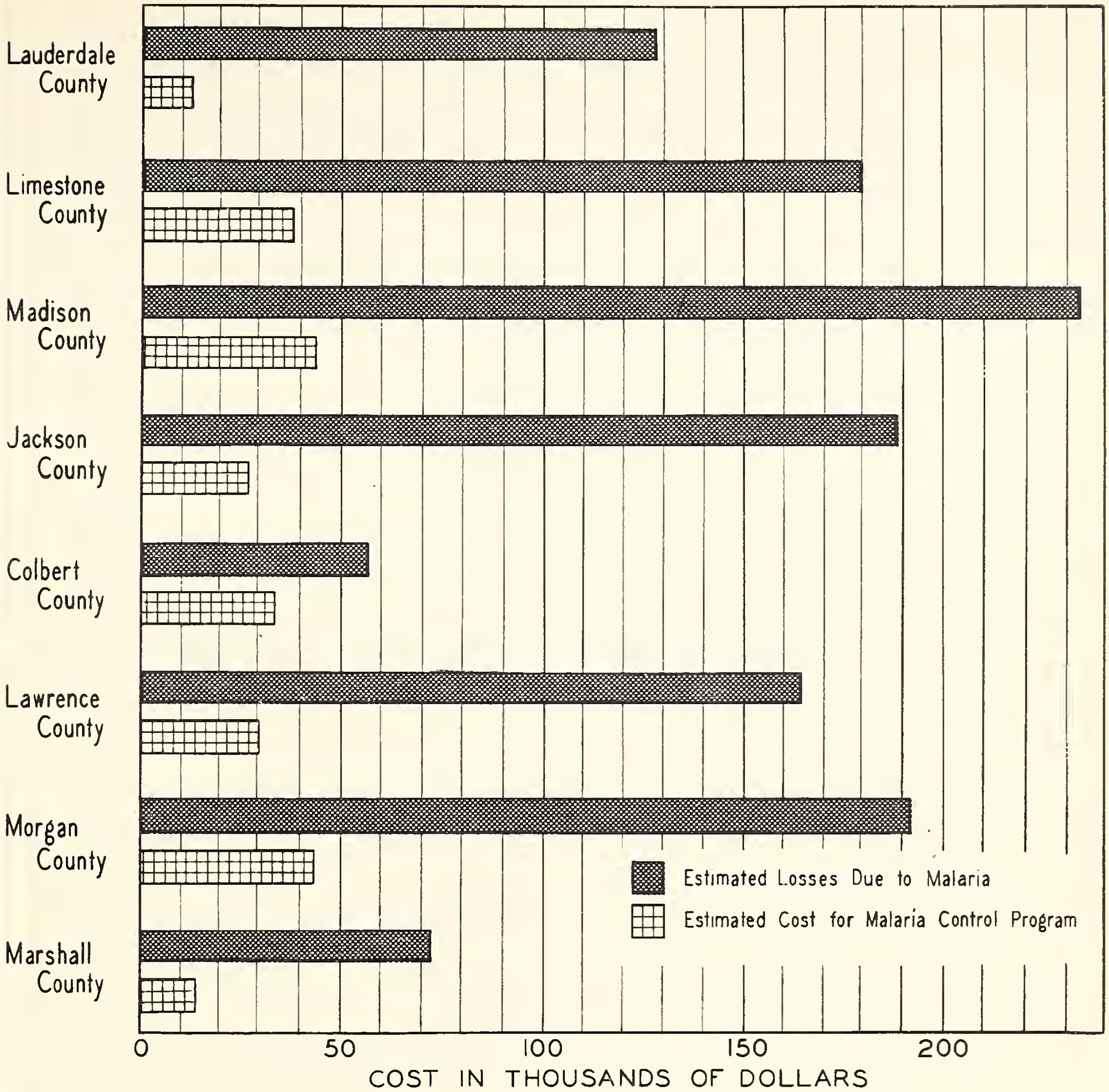
THE CAUSE, SYMPTOMS, AND CHARACTERISTICS OF MALARIA INFECTIONS IN THE TENNESSEE VALLEY

The Malaria Parasite, the Cause of Malaria

Malaria is caused by a microscopic animal parasite, first discovered in 1880 by Doctor Laveran, a French army physician. Later it was found that there were at least two other kinds of parasites besides the one discovered by Doctor Laveran. The diseases these three parasites produce and the method of their transmission from person to person are much the same. We might very properly speak of the "malaria diseases," but for the sake of convenience and because of their similarity we commonly think of malaria as being one disease.

Three Common Types of Malaria Produced by Malaria Parasites

The three types of malaria caused by the three kinds of parasites are tertian malaria, quartan malaria, and aestivo-autumnal malaria. All three types are characterized by alternating attacks of chills and fever. The principal difference in their symptoms is the length of time between the attacks. In tertian malaria the chills occur every other day, that is, on every third day. Hence the name, tertian, which is from a Latin word (tertius) meaning third. In quartan malaria the interval between chills is two days, the attacks occurring on every fourth day. The name itself is derived from a Latin word



NOTE: The costs of the establishment and maintenance for three years of adequate malaria control programs have been estimated on a county-wide basis. Data are included in reports of sanitary engineers of the Alabama State Health Department, 1939 and 1940. The estimated social and economic losses due to malaria and given for these counties were derived only for the populations living within one mile of the shorelines of Tennessee Valley Authority reservoirs. In 1939 these populations are estimated to have ranged from 6 to 20% of the total for the counties listed. For a discussion of the data employed and assumptions made, reference may be made to unpublished material, Review of Malaria Control Program, Tennessee Valley Authority, January 1940, Appendix B.

Fig. 2

COMPARISON OF ESTIMATED COST OF
MALARIA CONTROL
WITH
SOCIAL AND ECONOMIC LOSSES
FROM MALARIA
IN EIGHT COUNTIES OF NORTH ALABAMA
1936—1938

(quartus) meaning fourth. Aestivo-autumnal malaria is so-called because it occurs principally in the late summer and autumn months. This is the most serious form of malaria and causes the greatest proportion of deaths to a given number of cases. Other names for this form are "tropical malaria," or "malignant malaria." With this form, chills and fever may occur every day or may occur as in tertian malaria. The variations in intervals at which chills and fever occur in the three common types of malaria are illustrated in Fig. 3. Tertian malaria is by far the most common type in the South. Aestivo-autumnal malaria is present to a lesser degree, while quartan malaria is rarely found in this region.

The Life Cycle of the Malaria Parasite

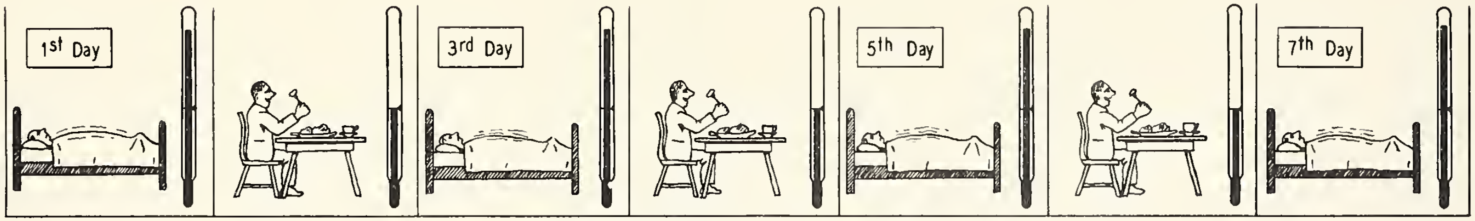
There are two phases in the development of a malaria parasite, the first taking place in the human body and the second in the body of a mosquito. In tertian malaria, which will be used as an illustration, the parasite is injected into the human blood stream by the bite of an infected mosquito. Shortly thereafter the parasite enters a red blood cell and begins to grow and multiply until from 16 to 24 new parasites are formed. The red cell then bursts, freeing the parasites which soon enter other red cells to undergo similar development. This phase is known as the asexual cycle. Each time a parasite multiplies in a red cell, the cell is destroyed, and in the course of time a great many red blood cells will be destroyed.

After several such divisions, some of the parasites cease dividing, but grow slightly larger and form what are called gametocytes, or "sex cells." When the female mosquito which transmits malaria takes a blood meal from an infected person, a certain number of these sex cells may be taken into the mosquito's stomach. Immediately thereupon male and female gametocytes unite, forming new cells which are able to bury themselves in the stomach wall of the mosquito. Here division takes place and continues until eventually young parasites break loose and wander through the mosquito's body to lodge finally in the salivary glands. The mosquito is now capable of injecting many of these young parasites with its saliva when it "bites" a person. Once again in the human body these parasites attack red blood cells. They grow and multiply creating a new case of malaria, a new source of mosquito infection, and continuing the cycle of parasitic development. The life history of the malaria parasite is illustrated in Fig. 4.

The period of time required for the development of the parasite in the body of the mosquito is about 14 days. This means that a lapse of practically two weeks must occur before a mosquito which has bitten a person with malaria parasites in his blood can transmit the disease to another person.

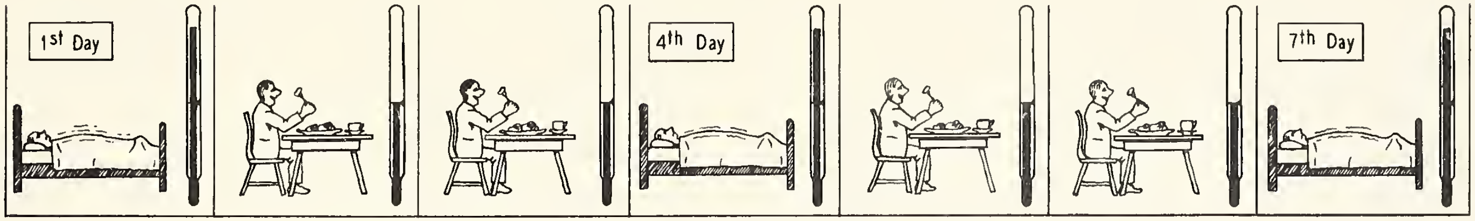
The Symptoms of Malaria and How They Are Produced

The principal symptoms of malaria are chills and fever, anemia, and an enlarged spleen. It is easy to see how these symptoms are produced when one understands how the parasites behave in the body.



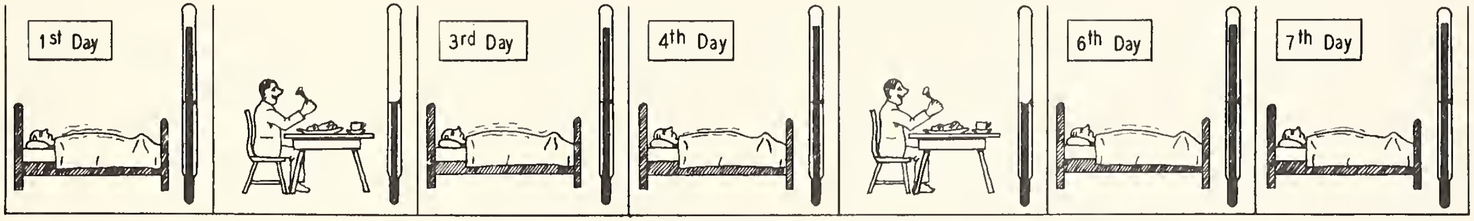
With Chills and Fever Every Other Day

TERTIAN



With Chills and Fever on First Day, Fourth Day, and in the Same Sequence Thereafter

QUARTAN



With Chills and Fever at Irregular Intervals or Sometimes Every Day

AESTIVO-AUTUMNAL

Fig. 3

THREE COMMON TYPES OF MALARIA

As already pointed out, the parasites grow and multiply within the red blood cells until the cells rupture and release the parasites into the blood stream, thus resulting in the destruction of many red cells. The decrease in the number of circulating red cells makes a person anemic and weak. For this reason, persons suffering from malaria often are pale, feel unequal to a good day's work, and are said to be chronically ill with the disease.

As the young parasites break out of a red blood cell, a poison is released into the blood stream. When many young parasites break out of large numbers of red cells at about the same time, the poison liberated is sufficient to cause the infected person to have a hard chill followed by a fever.

The spleen is a firm reddish-grey organ in the abdomen. Normally it is about the size of a small flattened orange. One of its functions is to filter out and destroy foreign bodies circulating in the blood. In malaria the spleen becomes very active in the destruction of parasites, which are really foreign bodies, and in removing the waste remnants that are produced by the wholesale destruction of red blood cells. The spleen becomes greatly overworked in this task and increases in size to take care of the extra burden placed upon it. Frequently, in malaria, this greatly enlarged spleen can be felt as a boggy mass projecting far below the ribs on the left side of the abdomen, and sometimes it is called "ague cake." It may be five or six times as large as normal--sometimes even larger.

Relapses

It usually takes from eight months to as much as five years for the human body to destroy completely all of the parasites of a single malaria infection. When quinine or some other drug is taken early in the course of the disease, many of the parasites will be killed and the symptoms of the disease will disappear temporarily. From time to time, however, those parasites not killed will increase in numbers sufficient to cause chills and fever again, and the person is said to have a relapse.

It is a striking fact that a great many relapses tend to occur in the late spring before the mosquito-breeding season begins. These illnesses are due to infections contracted during the previous fall or even earlier. No one has been able to explain the exact reason that relapses occur. They may flare up at any time, whenever there are enough parasites in the blood to produce symptoms of the disease. A great deal of study on this point, however, seems to indicate that relapses are due, in part, to the increasing temperature of the air during the spring season. Another possible explanation of relapses is that unusual physical exertion combined with hot weather may be a contributing cause. Plowing is started and other heavy labor about a farm is intensified with the first warm days of spring, and it seems likely that these circumstances play a part in the occurrence of relapses. Sudden shock, such as breaking an arm or leg, may also tend to bring about relapses as do changes in altitude and climate.

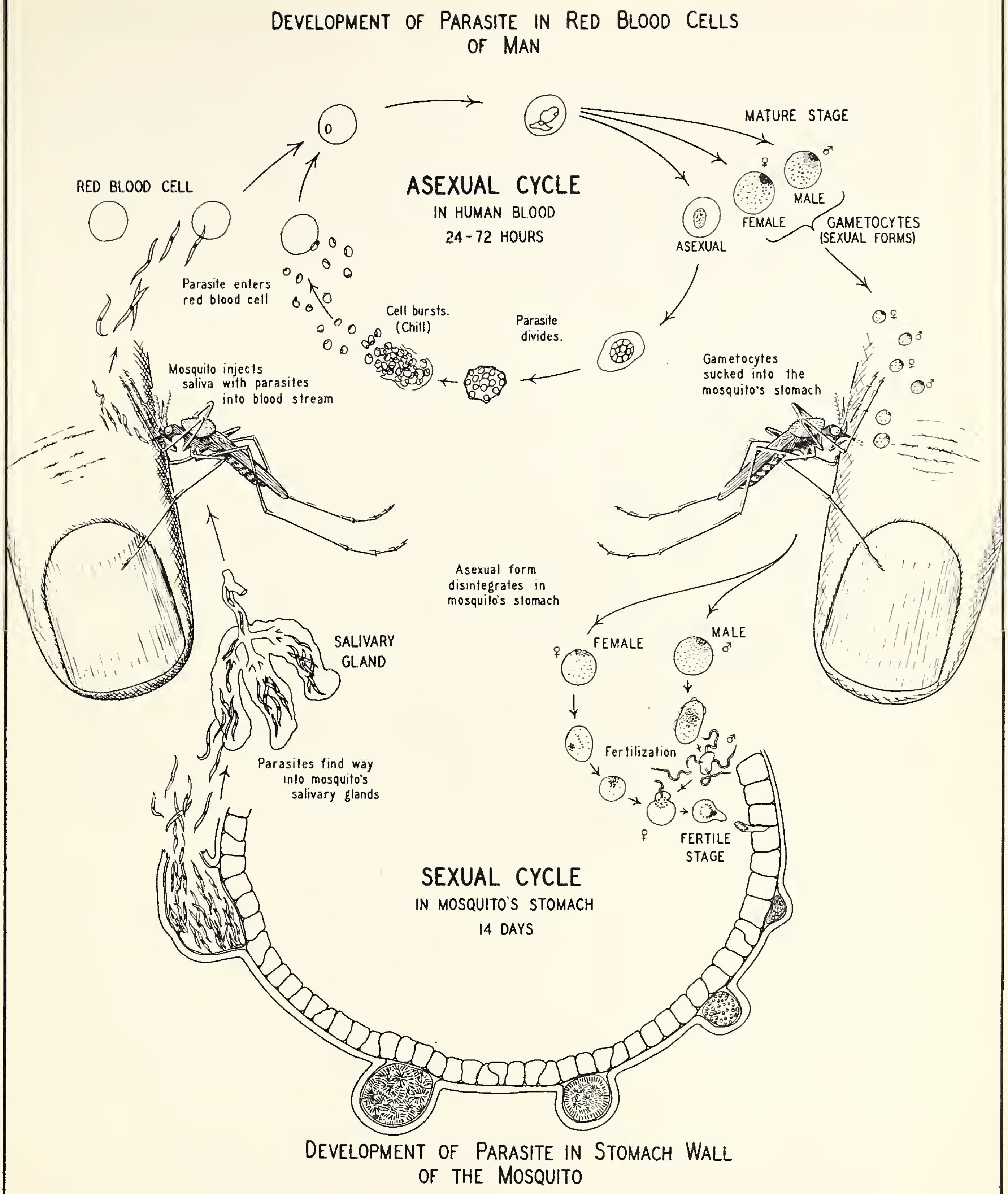

DEVELOPMENT OF PARASITE IN RED BLOOD CELLS OF MAN
MATURE STAGE
RED BLOOD CELL
ASEXUAL CYCLE
IN HUMAN BLOOD
24-72 HOURS
♀
♂
MALE
FEMALE
GAMETOCYTES
(SEXUAL FORMS)
ASEXUAL
Parasite enters red blood cell
Cell bursts. (Chill)
Parasite divides.
♀
♂
♀
♂
Gametocytes sucked into the mosquito's stomach
Mosquito injects saliva with parasites into blood stream
Asexual form disintegrates in mosquito's stomach
SALIVARY GLAND
♀
FEMALE
MALE
♂
Fertilization
♂
Parasites find way into mosquito's salivary glands
♀
FERTILE STAGE
SEXUAL CYCLE
IN MOSQUITO'S STOMACH
14 DAYS
DEVELOPMENT OF PARASITE IN STOMACH WALL OF THE MOSQUITO

Fig. 4

LIFE HISTORY
OF THE
MALARIA PARASITE
IN MAN AND THE ANOPHELES MOSQUITO

"Sexual Cycle in Mosquito's Stomach" reprinted by permission from "Introduction to Human Parasitology" by Chandler, published by John Wiley & Sons, Inc. Remainder of chart adapted from United States Public Health Service Bulletin No. 170.

Immunity

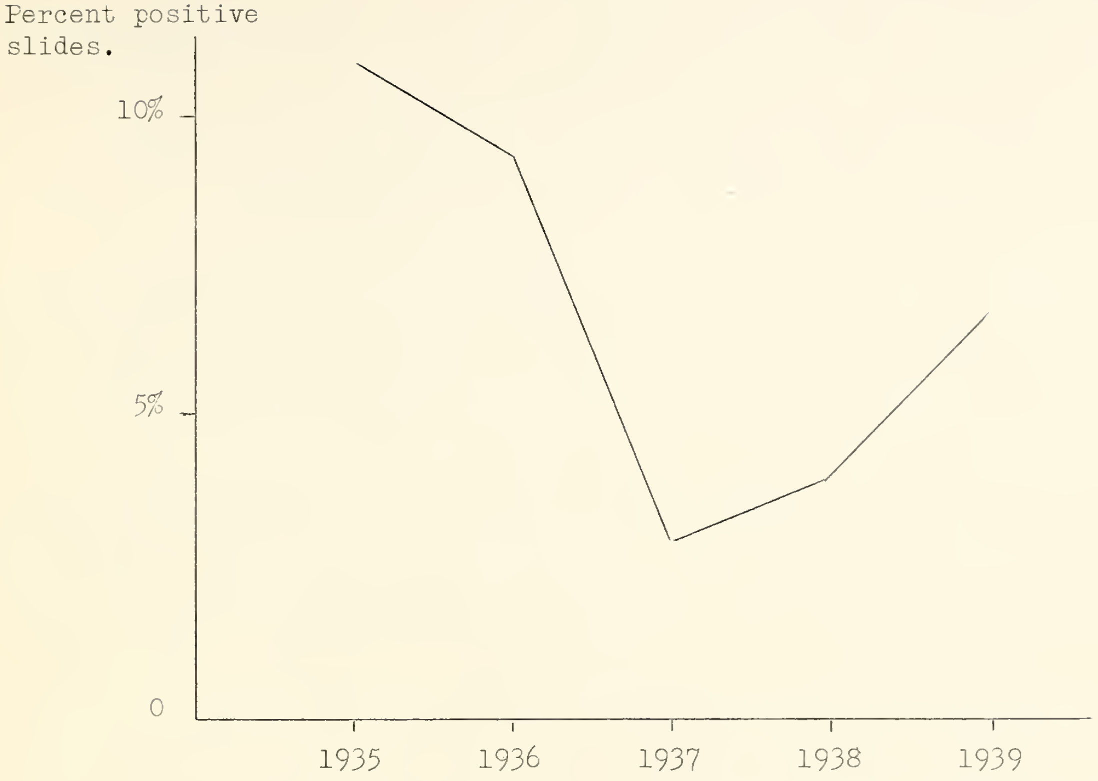
In the case of many diseases, such as measles, smallpox, chickenpox, and typhoid fever, once a person has recovered from an attack he is in little danger of having another attack, and he is said to have immunity. In malaria a certain amount of immunity is built up in the body of the person having the disease, but it is of a peculiar type and not nearly so strongly protective as is that which follows attacks of the diseases just mentioned. In other words, infections with the malaria parasite do not give the lasting immunity that often occurs in other diseases.

Epidemic Cycles

It is possible that variations in immunity partially explain differences in the total amount of malaria found in a region from year to year. In the Tennessee Valley region, for example, at intervals of about five years, perhaps sometimes seven years, there is a very considerable increase of malaria. These are known as "epidemic" years, and in some communities nearly everyone has malaria at some time during the summer. In the period between epidemic years, the total amount of malaria in any one year is always lower than during an epidemic year. During the years immediately following an epidemic year, there is a gradual decline until a low point is reached about the third year following the epidemic. After the low point has been reached, prevalence of the disease increases at a rate which usually is greater than the rate of decrease. This wave-like character of malaria prevalence is sometimes called an "epidemic cycle."

One theory which has been developed to explain this phenomenon is that in epidemic years nearly everyone has malaria, so that in the year following more people have developed immunity to the disease than is usually the case. In the course of time, however, children are born and populations shift; as a consequence the high level of general immunity to malaria is lost. The stage is then set for another epidemic.

From a practical standpoint, it is important to know the position of any year in the malaria epidemic cycle of a given place. Almost any malaria control measure that is undertaken in the years following an epidemic is likely to be accompanied by good results, and control measures instituted just before an epidemic may appear to show bad results, if measured in terms of the amount of malaria occurring in one year in the population which is being protected by the control measures. The epidemic cycle of malaria in the Tennessee Valley since 1935 is shown in Fig. 5. The percentages used in figuring this cycle are based on the number of positive blood films of school children within the one-mile zone of the Tennessee River.



EPIDEMIC CYCLE OF MALARIA, 1935 - 1939, IN THE ONE MILE

ZONE OF THE TENNESSEE RIVER LAKES.

Fig. 5.

MOSQUITOES AND MALARIA

The Malaria-Transmitting Mosquito in the Tennessee Valley--(Anopheles Quadrimaculatus)

The mosquito which is responsible for carrying the malaria parasite from person to person belongs to a group, or class, known as Anopheles mosquitoes. On the wings of all Anopheles mosquitoes are scales which tend to form characteristic patterns. Another characteristic of Anopheles mosquitoes is that they rest and bite while "standing on their heads." In the Tennessee Valley are five of the nine species of Anopheles mosquitoes found in the United States. However, only one of these species is known to transmit malaria in this region. This mosquito is called Anopheles quadrimaculatus, the term quadrimaculatus (quadri = four; maculae = spots) referring to the fact that certain of the wing scales of this mosquito are arranged into four small spots near the outer end of each wing.

How the Malaria Mosquito Transmits the Disease

The female mosquito alone is responsible for spreading malaria parasites from one person to another. This it does while biting a person to secure a blood meal, which is essential for the development of its eggs. As stated previously, the parasites are found in the mosquito's saliva and in the biting process are injected into the person along with some of the saliva (Fig. 4). Thus it may be seen that as far as the mosquito is concerned, the transmission of malaria is incidental to a more fundamental life process.

Many studies have been made to determine whether the malaria mosquito prefers human blood to other kinds of blood. Those made in the Tennessee Valley region show that Anopheles quadrimaculatus makes little distinction between the blood of human beings and the blood of cows. Apparently, it does have a preference for these bloods as compared with blood from other animals.

Once a female mosquito is infected with malaria parasites, it is always infected; but, after the parasites have been present in the salivary glands of a mosquito for about three weeks, they begin to degenerate. By the time these parasites are 50 days old they have practically lost their power to produce infection. In that time, however, the mosquito will already have secured several blood meals, and may have transmitted malaria to several persons.

Life History of the Malaria Mosquito

Like other insects, the Anopheles mosquito passes through four distinct stages in its development: the egg, larva, pupa, and adult. These stages are pictured in Fig. 6. Although very often the Culex or common pest mosquito and the Anopheles mosquito are mistaken for each other, the differences between them are distinct. The most important of these differences are shown in Fig. 6.

> 1. Egg. Recent investigations are disclosing that the malaria mosquito of the Tennessee Valley region begins its egg-laying during the warmer days in February. A few females come out of their winter quarters where they have been hibernating, secure a blood meal, and deposit their eggs in suitable pools of water. They keep this up all during the latter part of the winter and early spring. The eggs hatch but the larvae develop very slowly, not becoming transformed into pupal and adult stages until the temperature is right. In North Alabama and Western Tennessee this time is reached about the latter part of April when the daily minimum water temperature begins to average about 68° Fahrenheit or more, and the atmospheric temperature about 70° Fahrenheit. These temperatures mark the beginning of the active breeding season of Anopheles quadrimaculatus. In the more southerly part of the Valley this season usually extends from about May 1 to October 1.

The eggs of the Anopheles are deposited singly, each one floating by means of a partly inflated envelope that surrounds it. Eggs of the common pest mosquito, in contrast, are laid in clusters or floating "rafts."

2. Larval Stage. When the season is under way and the temperature conditions are favorable, the larvae of the Anopheles emerge from the eggs within from one to five days after the eggs are laid. The larval stage usually lasts from five to nine or more days, the length of time depending upon the abundance of food and the temperature of the water. During this period the larvae, or "wigglers" as they are often called, feed heavily on microscopic plant and animal life in the water. They grow rapidly, and as they enlarge in size they shed their skins. This they do four times.

The larvae of Anopheles mosquitoes spend most of their time at the water surface. They feed there, and when resting, lie parallel with the surface. When moving, they travel along at the surface, also. The larvae of the pest mosquitoes, on the other hand, rest with their bodies suspended at an angle from the surface, and are often seen diving below to feed.

3. Pupal Stage. The larva changes into the pupal stage at the last shedding of skin. During the pupal stage no food is taken, but internal changes are occurring nevertheless. The pupae, often called "tumblers," are frequently seen moving rapidly about in the water. The pupae of pest mosquitoes resemble those of the Anopheles very closely. The character which is most easily observed is the shortness of the breathing tubes of the Anopheles pupae. This difference can be seen in Fig. 6 where the breathing tubes of these pupae are so short as to cause indentations in the surface of the water while the longer breathing tubes of the Culex pupae do not. From twenty-four to forty-eight hours are spent in this stage before the adult mosquito finally emerges. In North Alabama, under favorable temperature conditions, the whole period from egg to adult requires only slightly more than a week.

4. Adult Mosquito. When the adult mosquitoes emerge they are as large as they ever will be. Any differences in sizes between adults are due to the differences in sizes of larvae, and these in turn are determined for the most part by the amount of food available.

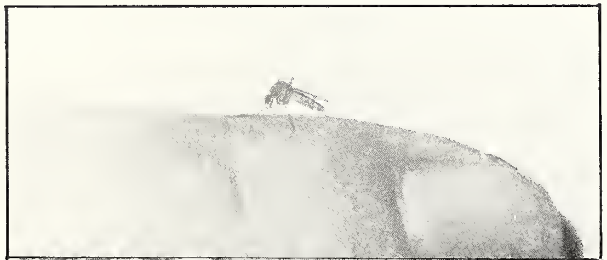
The adult Anopheles mosquito may be identified by her characteristic biting position. She bites "standing on her head" while the adult of the common pest mosquito keeps her body close to the skin of the person she is biting.

The adult female mosquito may live for as long as two months, but the male mosquito, whose function it is to fertilize the eggs of the female, has a shorter life span. The female mosquito during its existence will take several blood meals and lay several batches

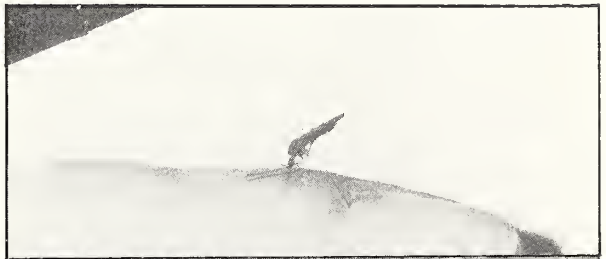
LIFE HISTORY OF TWO MOSQUITOES

CULEX

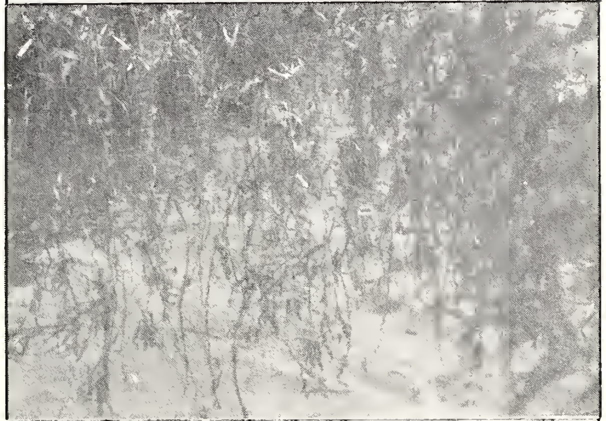
ANOPHELES

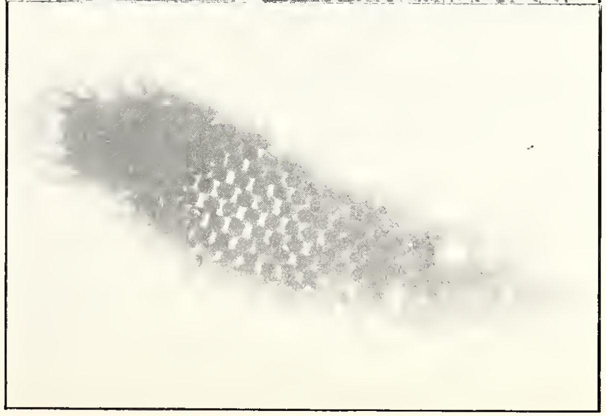


Adults biting.

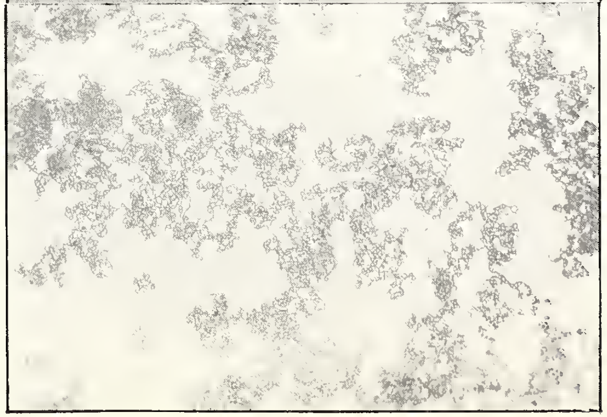


Breeding places.





Eggs



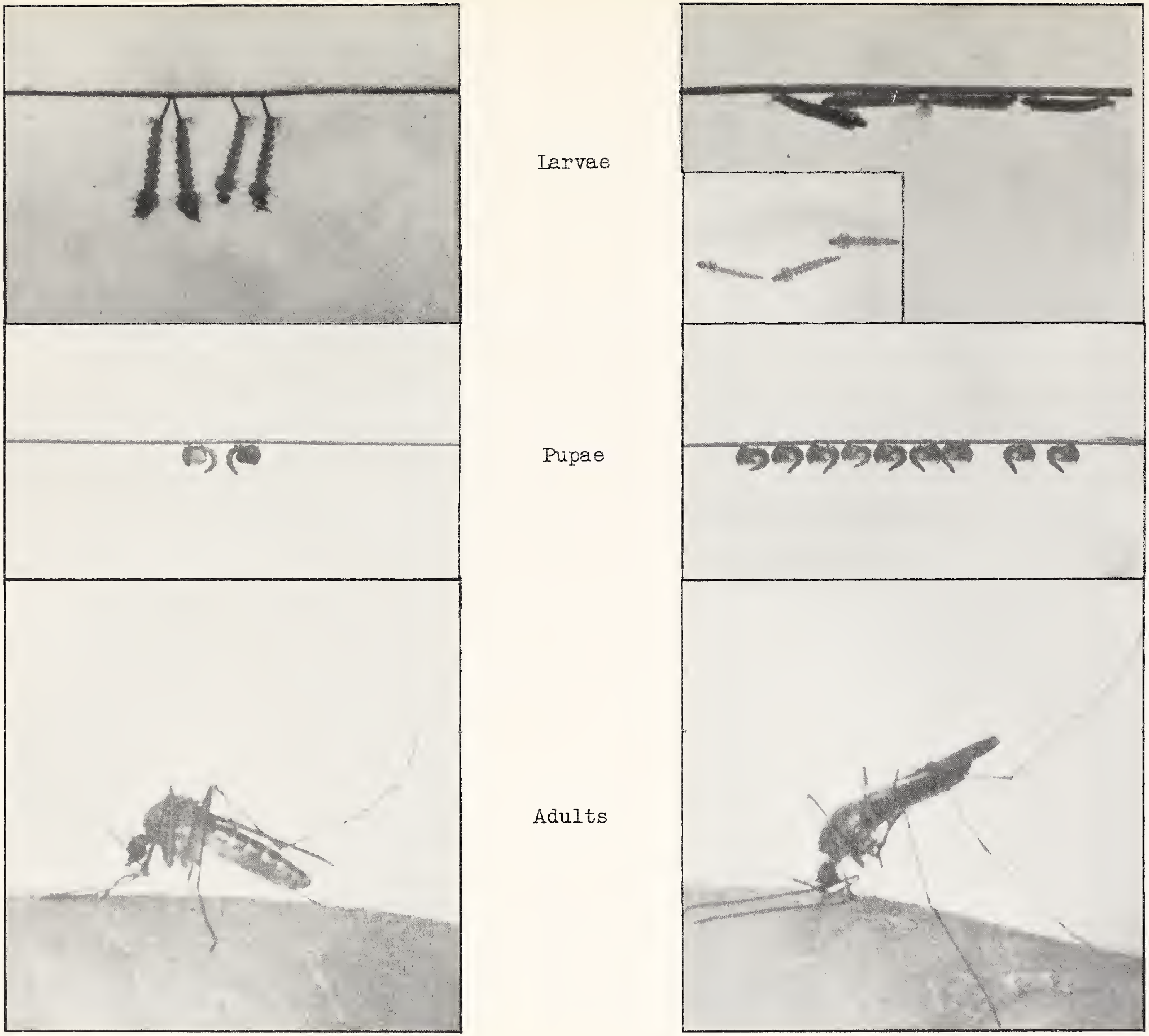


Fig. 6

> of eggs. It does most of its biting at twilight or during the night, especially in the early evening hours.
>
> As the weather grows colder, at the end of the breeding season, those female mosquitoes that are alive take their last blood meals. But now, the blood, instead of helping in the development of eggs, is used to form fat which is stored internally as "fat bodies" to serve as food to sustain life during the winter months. By instinct the mosquitoes seek places which will be relatively warm and protected during the winter. In the Tennessee Valley, throughout the cold weather, these adults may be found resting quietly in caves, barns, cellars, vegetable pits, beneath the weatherboarding of houses, and in other similar places (Fig. 7).

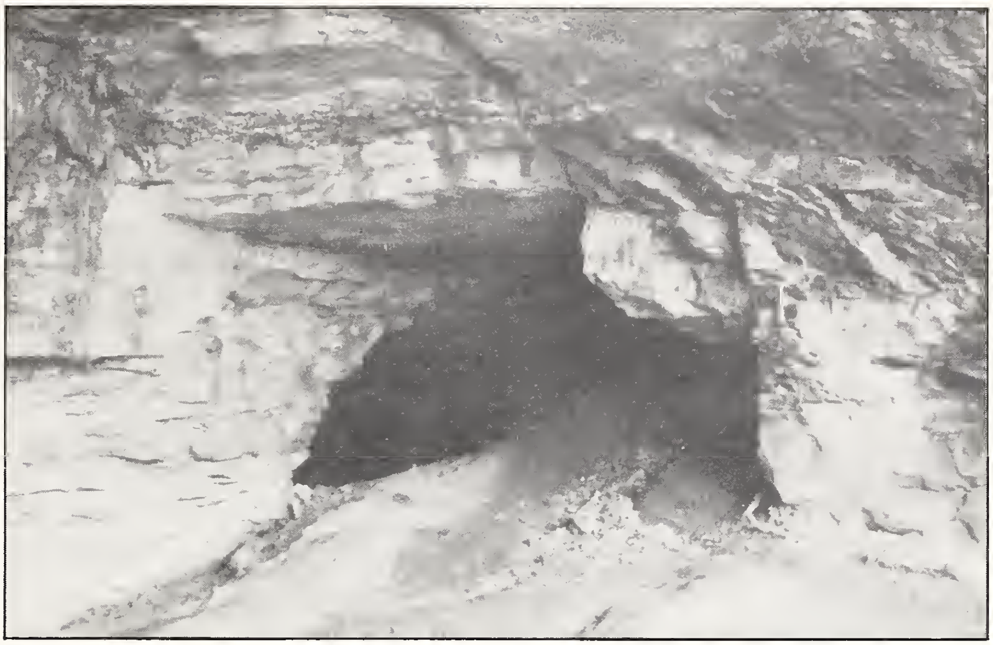
Breeding Places of the Malaria Mosquito

It has already been stated that the female mosquitoes lay their eggs on water and that the larval and pupal stages develop in water. The nature and location of the water determine to a great extent the kind of mosquitoes that will breed in it. Typical *Anopheles quadrimaculatus* breeding places are pictured in Fig. 8.

In the case of the *Anopheles* mosquito, quiet and usually clear pools of water provide the most favorable breeding places. These are more commonly found under natural conditions than under man-made situations. In the Tennessee Valley, quiet inlets on lakes, lime sink ponds, and swamps with not too stagnant water are typical breeding places for the *Anopheles* mosquito.

Vegetation which often grows in such places furnishes protection for the larvae from the minnows which prey upon them. Reeds and other plants growing along the edge of a pool collect bits of material floating on the surface, and this material provides further protection.

Since some of the most important control measures involve finding the places where larvae exist and, if possible, destroying these places, it is just as important from the standpoint of time and efficiency to know where to expect not to find the larvae of *A. quadrimaculatus* as it is to know where to expect to find them. Contrary to common belief, these larvae are not found in artificial containers such as empty automobile tires, egg shells, tin cans, or temporary pools of water such as may form in animal or cart tracks in barnyards. These are common breeding places for the pest mosquito, but not for the *Anopheles*. We do not find the larvae of *Anopheles quadrimaculatus* in flowing streams nor, in fact, in any water which is in perceptible motion. Neither do we find them in pools that have been polluted heavily with sewage, such as septic tanks and cesspools, although in such situations the larvae of a certain pest mosquito are commonly found.



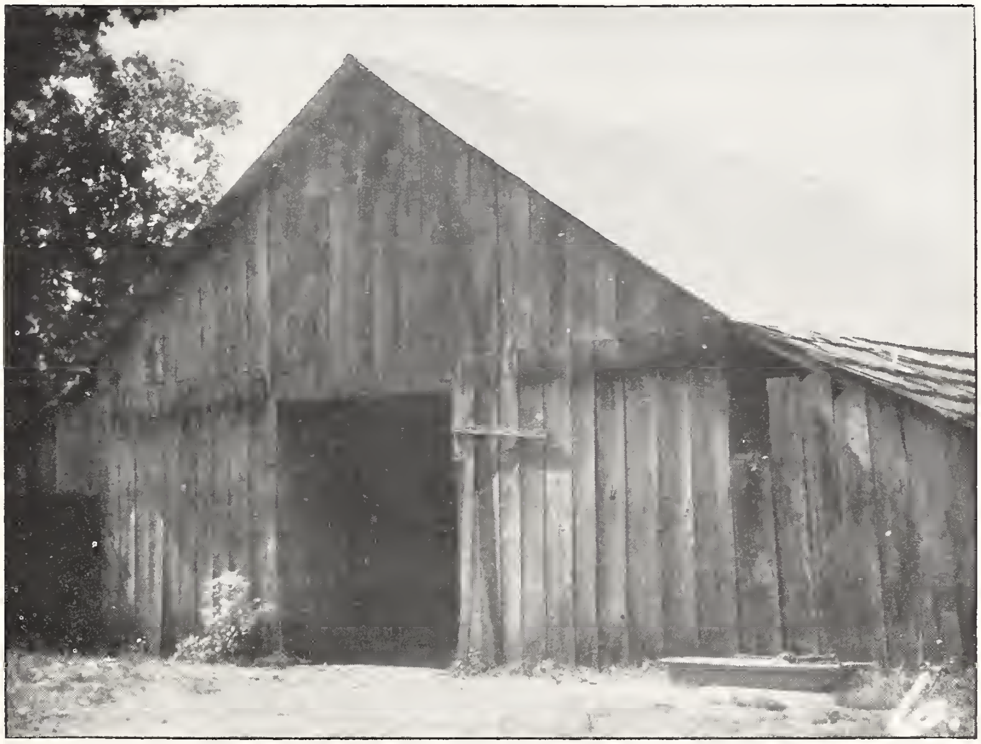


Fig. 7. Adult mosquitoes may be found resting in caves, in barns and in similar places.

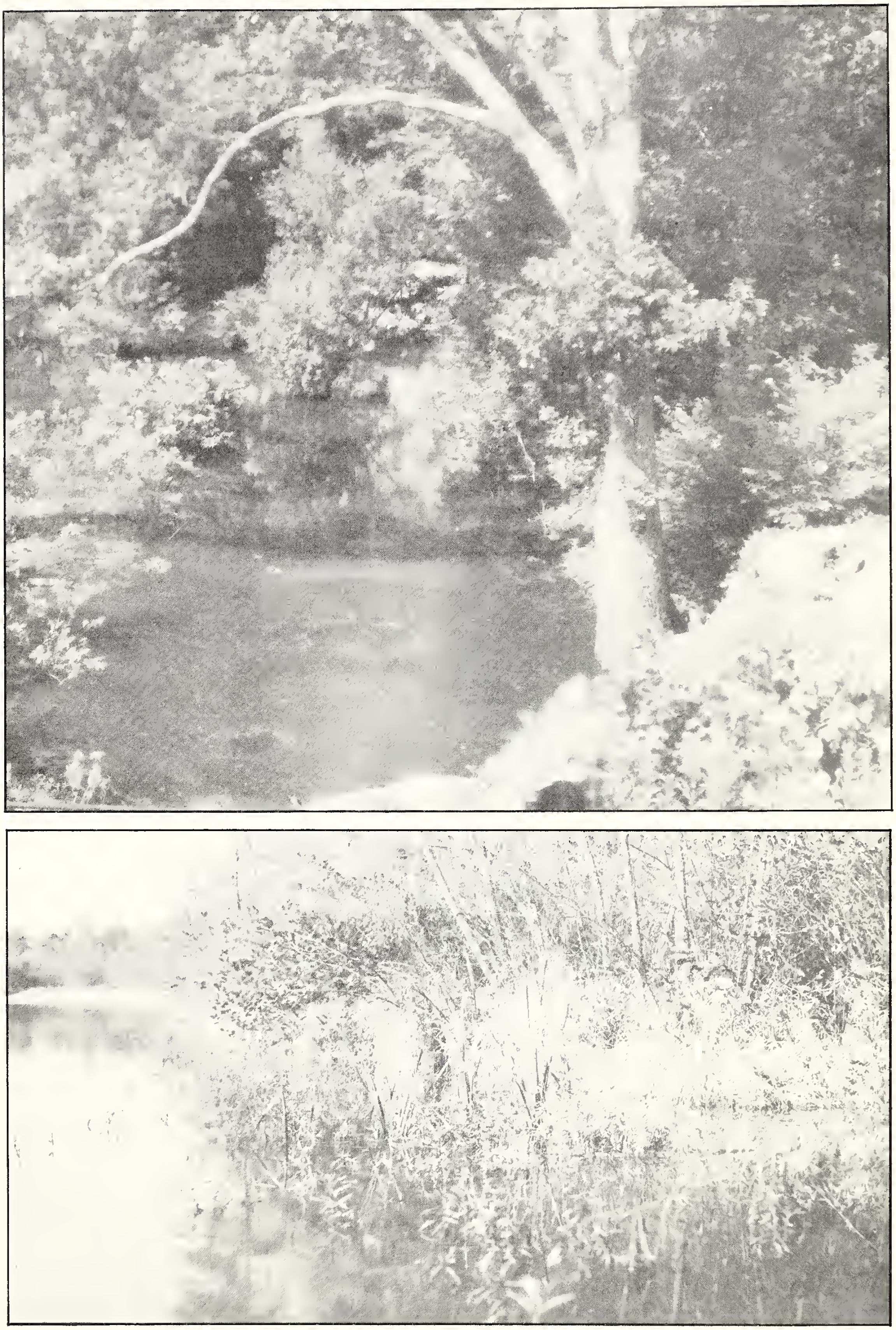


Fig. 8. Anopheles quadrimaculatus breeding places.

PREVALENCE AND DISTRIBUTION OF MALARIA IN THE TENNESSEE VALLEY

Factors Determining the Prevalence and Distribution

Malaria is found only where conditions are favorable for its establishment and continued occurrence. As already recognized, anopheline mosquitoes must be present in numbers sufficient to produce a problem. The presence and number of these mosquitoes are dependent on the extent of suitable breeding places for their growth and multiplication, as well as on conditions of temperature and humidity. Essential, too, is the presence of persons infected with malaria and persons free from infection to whom the disease may be transmitted. Furthermore, the mosquito must have access to both the infected and noninfected persons.

In the Tennessee Valley most cases of malaria are found within a mile radius of bodies of water that provide favorable breeding conditions for *Anopheles quadrimaculatus*. This is explained by the fact that the female mosquito of this species must sometimes go as far as a mile in order to secure the blood meal which it needs for the development of eggs. Rarely, however, does its flight exceed a mile, and more often the distance is much shorter, for blood usually can be found nearer at hand. By far the greatest number of cases of malaria are within one-half a mile of breeding places. This is a condition which is characteristic throughout the Valley, and in fact in all the Southern States where *Anopheles quadrimaculatus* is the carrier of malaria. The distribution of cases of malaria in relation to bodies of water is illustrated in Fig. 9. In Limestone County cases are concentrated along Elk River, Limestone Creek, Wheeler Reservoir, and in close proximity to the chain of permanent ponds scattered through the center of the county from south to north.

Factors That Produce Changes in Prevalence and Distribution

As breeding conditions change, the distribution and amount of malaria may also change. Before the impoundment of Lake Wheeler in 1937, malaria occurred all up and down the Tennessee River in the portion now covered by the Lake. It was most intense in places where ponds of water were present near the River, since these ponds provided especially favorable breeding places for mosquitoes. In 1939 malaria had practically disappeared in many places, while in other places its occurrence was much the same as in 1934.

This variation in occurrence of malaria in the same region can be understood in the light of the changes that took place along the Tennessee River between 1934 and 1939. When Wheeler Dam was completed, what had been a river channel several hundred feet wide became flooded into a lake several thousand feet in width. Many ponds which were producing malaria in 1934 had been covered by the water of Lake Wheeler by 1939, or had been drained by the Tennessee Valley Authority in its control program along the mile zone of the Lake. On the other hand, in the central portions of the Lake particularly, by 1939, the water extended far beyond the old channel and, because it was very shallow and contained vegetation, tended to form new breeding places for mosquitoes. The conditions which cause shallow water in the central portions of lakes in North Alabama also tend to favor the formation of natural ponds. For this reason, more breeding places are apt to occur in association with the central portion of the lakes, and in these portions control of mosquitoes is therefore more difficult.

In view of the fact that little has been written about the history of malaria in the region as a whole for the past 100 years, it is difficult to understand the reason for the changes that have occurred over this time which have resulted in the practical disappearance of the disease from East Tennessee. The following explanation, although speculative, is supported to some extent by general historical data. It is presented because of its significance in pointing to the need for unending vigilance in matters of control.

In the sixty years prior to 1910, the general course of the River remained much the same, and there was no major alteration in the physical features of the Valley. Natural potentialities for mosquito production associated with the River probably changed very little, and the reason for the practical disappearance of malaria from East Tennessee must, therefore, be sought from another direction. Among probable influences operating to accomplish this disappearance, there may be considered the fact that the upper portion of the Valley was settled some years prior to the middle and lower portions; that the proportion of land used for agriculture in East Tennessee was originally comparatively limited in extent, being confined to narrow valleys between numerous hills; that inundation of flood plains was less frequent and more transitory; and that the drainage of flat lands for agricultural use was accelerated because of its relative sparsity. Since there were few large holdings of agricultural lands and small tracts held by single owners were the rule, the result was a diversified agriculture with a relatively stable white population living on the land it farmed. Such a rural economy produced greater individual economic independence and perhaps better average living conditions than those existing in the middle and lower Valley where larger units of land were farmed with tenant or slave populations. As other sources of power became available, small water power units were abandoned, and the reservoirs silted up.

In somewhat striking contrast were conditions in North Alabama and West Tennessee where cotton farming was practiced on a large scale, resulting in individual ownership of large tracts of land, the considerable use of slave labor with the resulting continuous introduction of parasite carriers from endemic coastal regions, and following the Civil War, the extended use of tenant farm labor.

In brief, malaria has receded from the upper third of the Tennessee Valley, and in that region is no longer a disease of importance, whereas in the middle and lower thirds, the recession has not been proportionate. This decrease in East Tennessee has been associated with a decline in natural mosquito breeding areas, a gradual eradication of artificially produced breeding surfaces, with the maintenance of a stable native-born population that, in

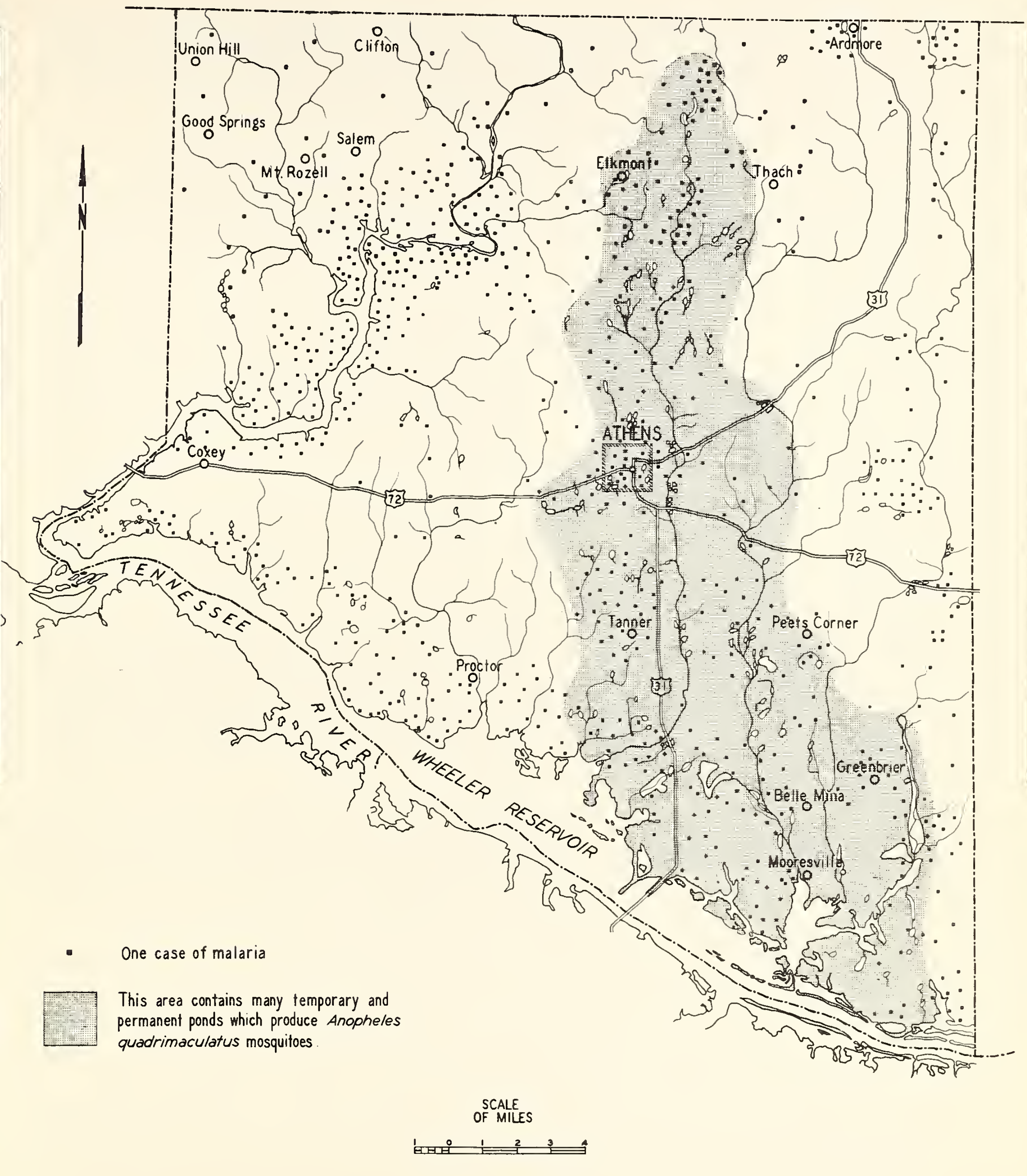


Fig. 9

REPORTED CASES OF MALARIA
IN LIMESTONE COUNTY
ALABAMA
1938

Taken from a Study and Analysis of Malaria in Limestone County, Alabama 1937 - 1939, Alabama State Department of Public Health, 1939.

all probability, was relatively well-housed. The logical conclusions are that if water is kept in motion in the Tennessee Valley, there is little opportunity for anopheline breeding in significant quantities; that if water is impounded the converse is true, and that malaria can occur anywhere in the Valley and has occurred in every section of it . . .

In 1912, a portion of the Tennessee River was impounded behind Hales Bar Dam without preparation of the reservoir for the prevention of mosquito breeding. A widespread epidemic of malaria in the population living contiguous to the shoreline resulted, and endemic foci were established which are still existent.

In 1927, a pool was impounded on the Falling Water River near Cookeville, Tennessee, without preimpoundage preparation. Despite the fact that this lake is high on a bench of the Cumberland Plateau in a region where there had been no malaria for many years, the resulting epidemic affected practically the entire population within the flight range of mosquitoes breeding in the reservoir.

CONTROL OF MALARIA

Malaria Control Measures in General

It has been seen that if malaria is to be transmitted successfully, a chain of three events must occur. A female anopheline mosquito must bite a person infected with the malaria parasite; the parasite must undergo changes in the body of the mosquito which require from 10 to 15 days to complete; and the mosquito must then transmit these parasites to a well person who is susceptible to the disease.

In the fight against malaria throughout the world there are three principal methods of control, each one of which is directed toward breaking, at some point, the chain of events that has just been described. These methods are outlined below:

1. Measures directed against the malaria parasite:

    A. Use of drugs in the treatment of patients and carriers

2. Measures directed to protect persons from the bite of the mosquito:

    A. Mosquito-proofing
    B. Nets, repellents

3. Measures directed against the mosquito:

    A. Against the adult mosquito

- (1) Hand destruction
- (2) Fumigation or spraying

B. Against the larvae of the mosquito

- (1) Biological control

    - a. Elimination of breeding places through drainage and filling
    - b. Altering of breeding places so that they become unfit for the production of larvae

        - 1) Shoreline cleaning and removal of vegetation
        - 2) Water level fluctuation
        - 3) Predators

- (2) Chemical control of larvae--use of larvicides

    - a. Paris green and other dusts
    - b. Oils

- (3) Permanent control measures

This long list of control measures is evidence that the attack on malaria is no simple problem. Unquestionably, the most practical and effective of all the measures are those which are directed against the larvae of the mosquito. Other measures have their place, however, and along with the elimination of mosquito larvae contribute to the prevention of the disease. In the following paragraphs these measures will be discussed in some detail.

1. Measures Directed Against the Malaria Parasite.

A. Use of drugs in the treatment of patients and carriers. Quinine and atabrine are the most commonly used drugs in the treatment of malaria. When taken early in the disease and under proper medical supervision, they are helpful in checking the severity of the attack and in preventing relapses.

Valuable as these drugs are for treatment, they are far from effective as a principal measure of control. In fact, no drug has yet been found which is foolproof for either treatment or control. In the first place, no drug will prevent a person from becoming infected with parasites when he is bitten by an infected mosquito. Moreover, no drug can be relied upon to destroy all of the parasites when once they have become lodged in the body.

Even if a drug could be found that was perfect from the standpoint of treatment, there would be many difficulties in the way of its successful use as a malaria control measure. Many persons harbor malaria without showing symptoms of the disease. The only way to discover infection in these people would be to study their blood for evidence of the presence of parasites. Yet at any one time only about one-half of the people known to have malaria will show parasites through such a study. In other words, the parasites, although lodged in the body, cannot always be found in the circulating blood. This would mean that to control malaria in a malarious community through the use of drugs, all persons would have to be treated, regardless of whether or not the parasites could be found in their blood. This measure would be both expensive and impractical as compared with other methods of control.

2. Measures Directed to Protect Persons from the Bite of the Mosquito.

A. Mosquito-proofing. Complete mosquito-proofing of houses is the most effective way to protect man from mosquitoes. It involves covering all windows with 16-mesh wire, screening all doors with this wire according to specified plans which assure sturdy, tight-fitted structures; covering all cracks in walls, ceilings, and floors, and sealing tightly all fireplaces.[1] These measures are pictured in Fig. 10. Since the anopheline mosquitoes bite at dusk and during the night, not only homes but other buildings, such as schools and churches, occupied by people at night should be protected by mosquito-proofing. Moreover, if this is to be an effective control measure, people must stay within these protected buildings at the time when the mosquitoes are most active.

B. Nets and repellents. Bed nets (mosquito bar), face or head nets, and gloves probably offer some protection to those who must be exposed indoors or out. Some protection is afforded also by repellents, like oil of citronella, which may be used along with the nets.

3. Measures Directed Against the Mosquito.

A. Against the adult mosquito. Since it is the habit of adult anopheline mosquitoes to seek blood meals from human or animal sources, these mosquitoes may often be found inside of houses or barns. Various methods have been employed to destroy them in these confined places, the most common of which are swatting and the use of sprays.

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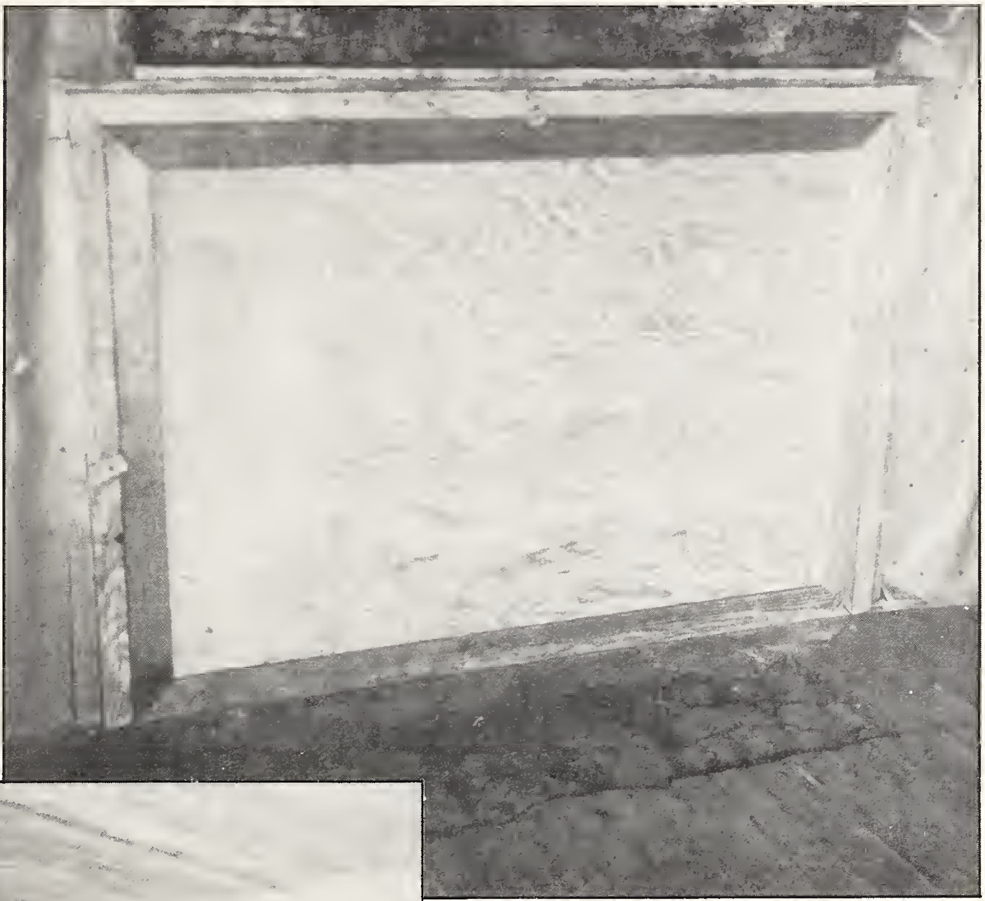
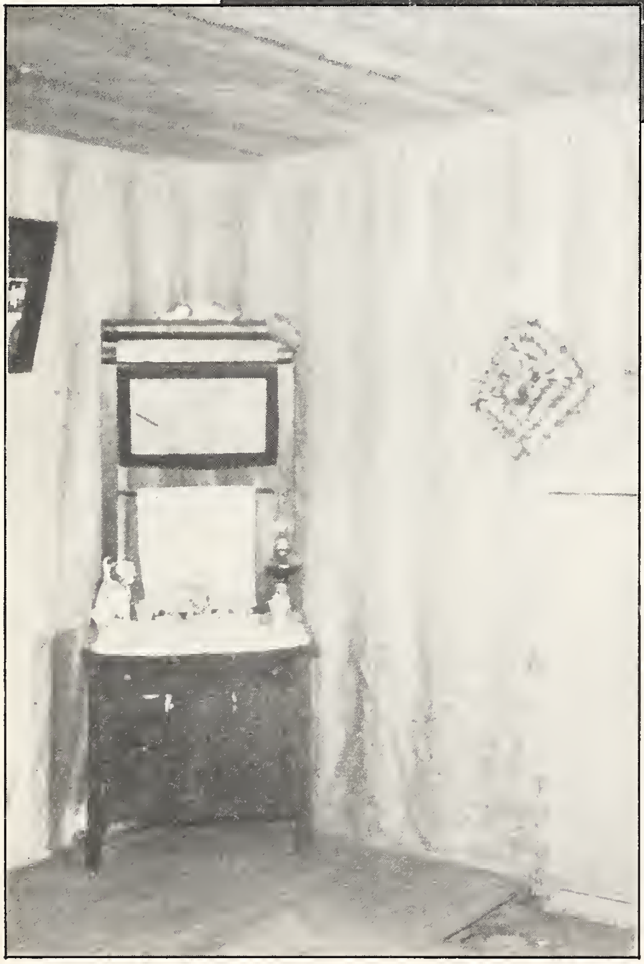
[1] See bulletins from county or state health departments for detailed instructions for mosquito-proofing.

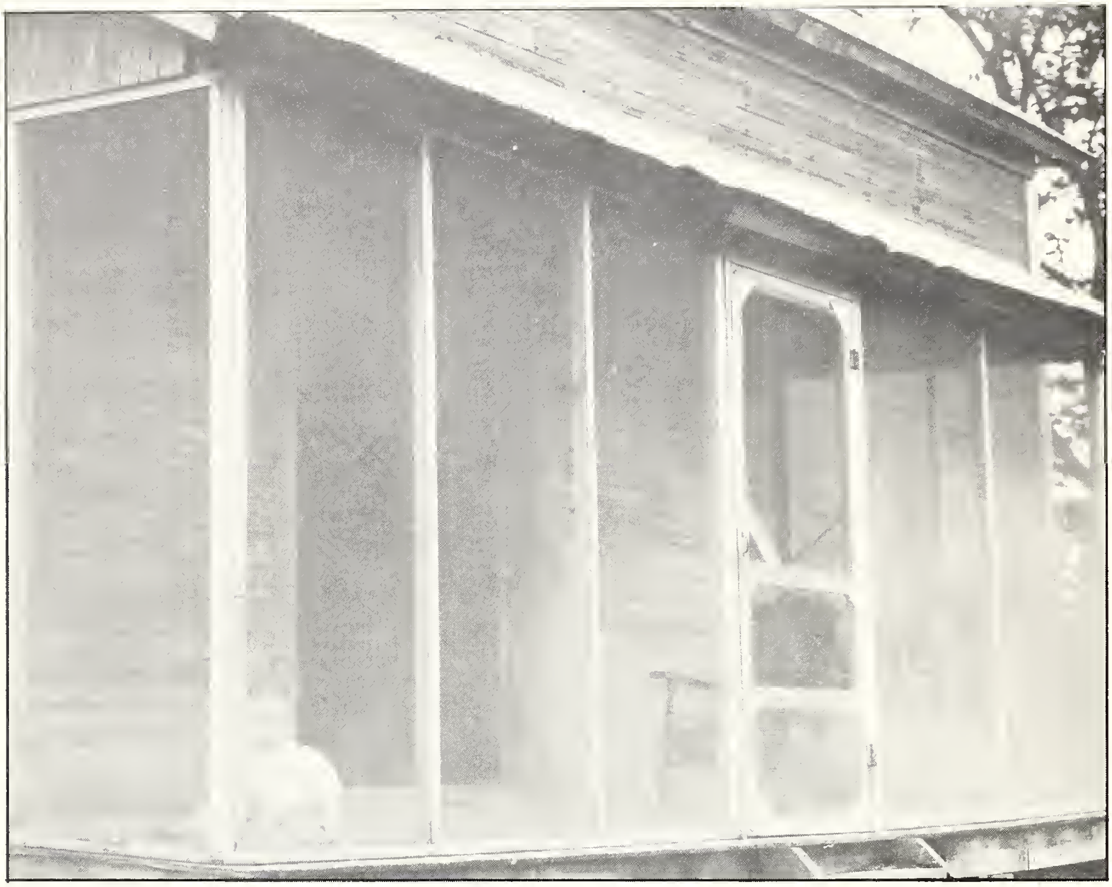


A fireplace screen.

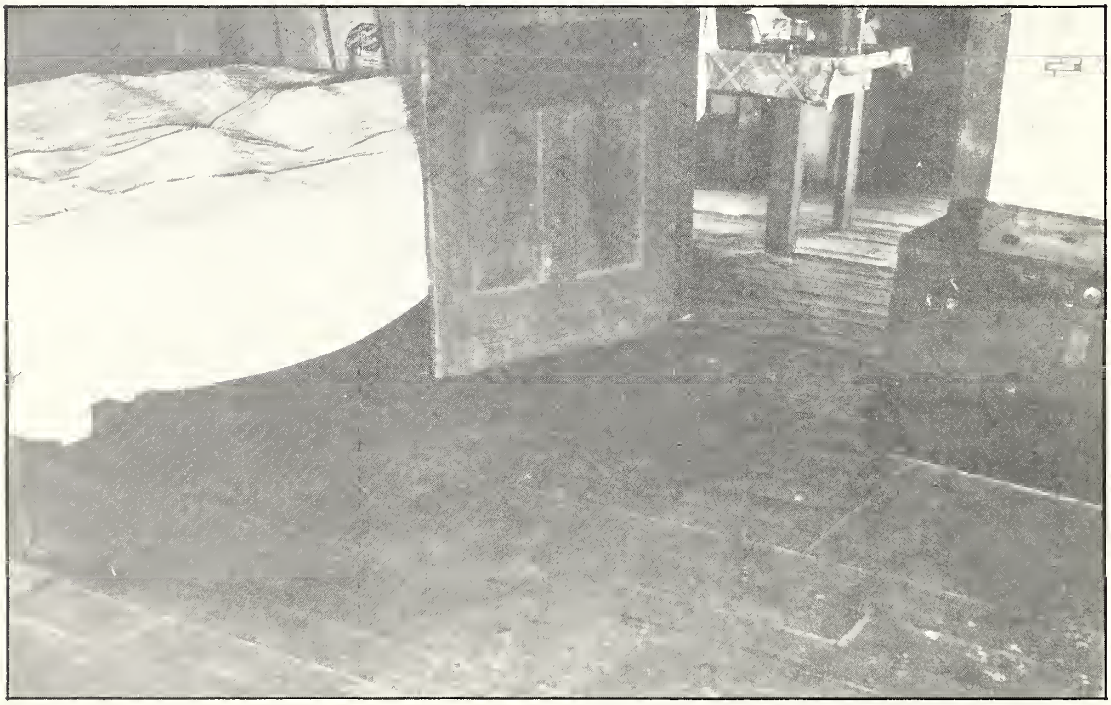


Walls covered with heavy paper.

Fig. 10. Mosquito-proofing.



Well constructed screen door, and screened porch. 16 mesh wire is used.



Floor covered with heavy roofing paper.

Fig. 10 continued.

(1) Hand destruction

During the daytime, favorite hiding places are behind pictures, under beds and chairs, in corners or cracks in the walls, in the corners of barns, and in fact in any dark spot where protection can be found. The hand swatter will be of help in destroying some, but more effective are sprays that can reach the less accessible places.

(2) Fumigation or spraying

A simple spray can be made consisting of:

1 gallon of mineral spirits or kerosene

1 pound of fresh pyrethrum powder, commercially known as insect powder, or the extract from one pound of pyrethrum

These ingredients should be mixed together thoroughly and permitted to stand 72 hours, when the settled liquid may be poured off or strained through a cloth. It is then ready for immediate use in a spray gun. To be most effective the spray should be broken up into a fine mist and directed toward the ceiling. All doors and windows should be closed before spraying and kept closed for at least 30 minutes thereafter. Mineral spirits and kerosene have about the same degree of inflammability. Mineral spirits has an advantage over kerosene in that it is not as greasy and is not as likely to stain clothing or the interior of the house.

Attempting to destroy adult mosquitoes by swatting or by the use of sprays may seem to have limited value since these mosquitoes may have laid eggs, or, if infected, have bitten a person susceptible to malaria. However, mosquitoes within houses are likely to have fed upon the residents who are infected, so that destruction of these mosquitoes may reduce the number capable of spreading malaria.

B. Against the larvae of the mosquito. There is a general agreement that the most satisfactory way to secure malaria control is through the control of anopheline larvae, either by entirely eliminating mosquito-breeding places so that the larvae do not have a chance to develop, or by altering these places so that they become unfit for the production of larvae. These measures are somewhat technical, however, and must be carried out under engineering supervision.

(1) Biological control

a. Elimination of breeding places through drainage and filling. Drainage is the method most widely employed for the elimination of breeding places. Drainage is commonly used to remove permanent accumulations of water, such as a pond; to connect ponds with flowing streams so that the water in the ponds will be kept in motion; and to provide a constant run-off of water from swampy places or ponds fed by springs or from land easily flooded after heavy rains. Fig. 11 shows a series of small quiet pools being transformed into a flowing stream. Sometimes breeding places can be eliminated by filling them with dirt or other material which will take the place of water. Still another method which is sometimes used on larger bodies of water, such as a lake, is to dike off that part of the lake which is providing the most favorable breeding area, then remove the water from it by pumping, and if necessary fill the land which has been left uncovered.

b. Altering of breeding places so that they become unfit for the production of larvae. As already shown, there are certain conditions in nature which favor the development of anopheline larvae. Among these are quiet, clear water; vegetation growing in this water; and flotage or debris which may collect around the vegetation. These conditions may also be found where water has been impounded for power, flood control, or navigation; in other words, where nature has been artificially altered for man's use. Ways must be found to convert both natural and artificial breeding places, which for various reasons cannot be controlled by drainage, into spots that are unfit for larvae production.

1) Shoreline cleaning and removal of vegetation. One important method of control is keeping shorelines of ponds, or impoundments, clear of vegetation which may encourage larval growth. Both hand and machine methods are used to remove vegetation which may accumulate along the edges and in the quiet inlets of these bodies of water. In Fig. 12 is shown an underwater cutter which removes vegetation difficult to reach by hand. The removal of all timber from man-made reservoirs prior to impoundment also has been found essential (Fig. 13).

2) Water level fluctuation. In recent years, fluctuation of water level has proved to be the most effective single control measure on impoundments where the elevation of the water can be controlled. This measure has been recommended widely by the United States Public Health Service, and much pioneer work with it has been done by the Alabama State Department of Public Health. When the level of the water is lowered rapidly during the mosquito-breeding season, the mosquito larvae are left stranded upon the shoreline where they die; or the movement of the water may

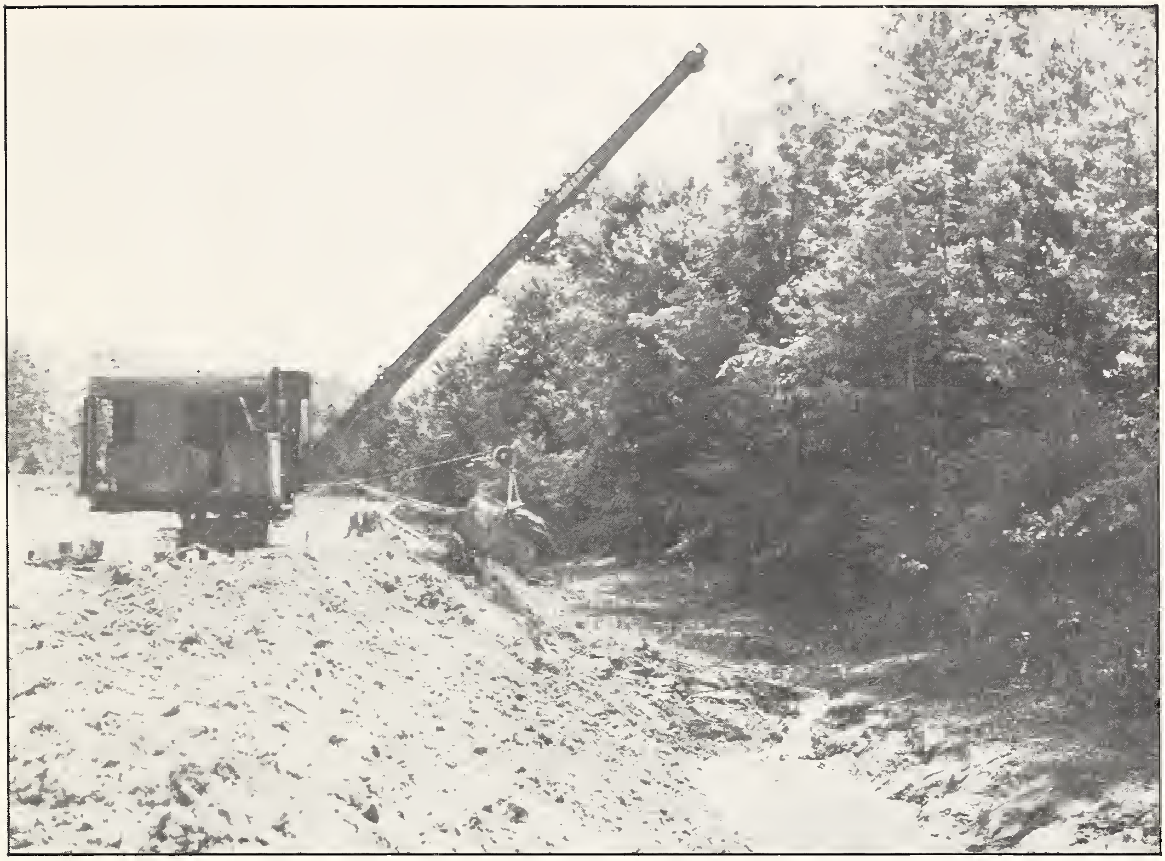


Fig. 11. A series of small pools being transformed into a ditch with flowing water.

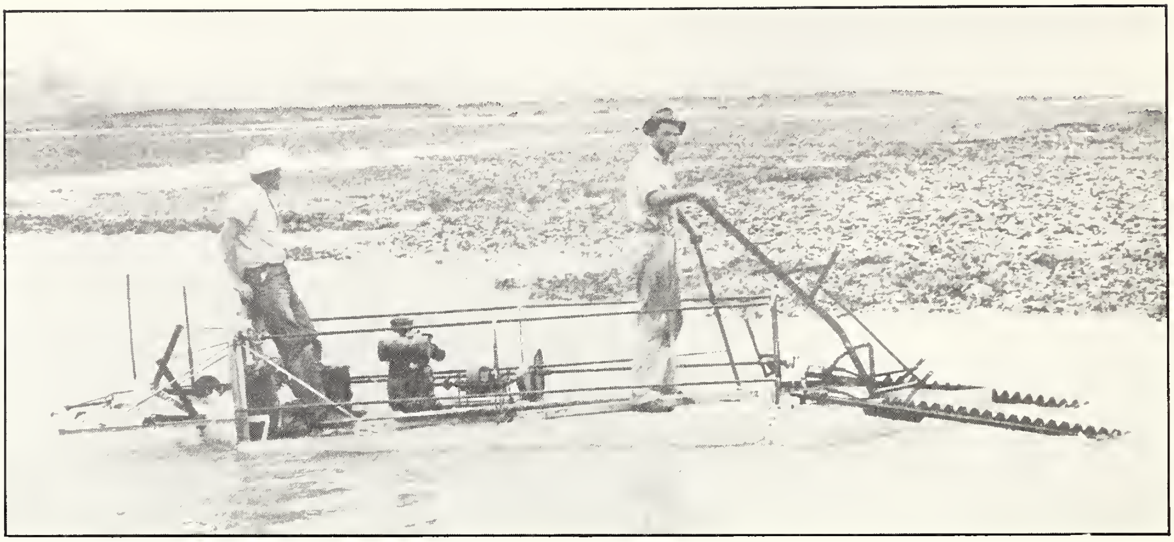


Fig. 12. An underwater cutter which removes vegetation difficult to reach by hand.

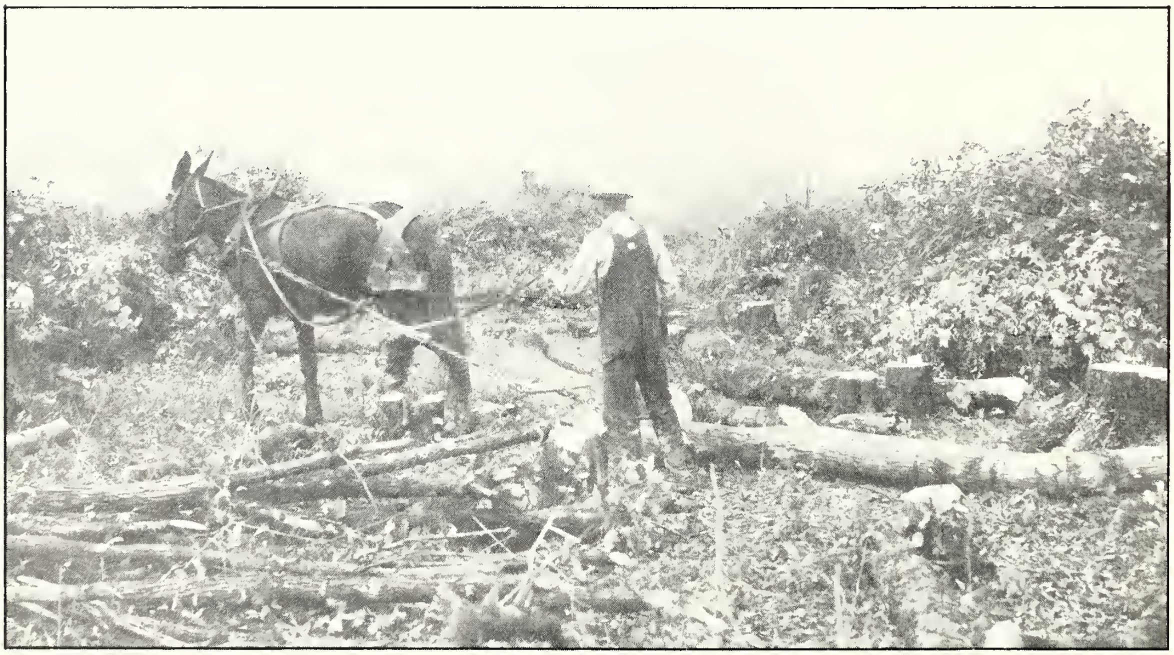


Fig. 13. The removal of all timber from each reservoir prior to impoundment also has been found essential.

dislodge them from vegetation and floating material, thus leaving them at the mercy of natural enemies and wave action.

It is common practice to lower a pool of water about one foot and then raise it to a level just below that from which it was lowered. If this procedure is followed each week throughout the malaria season, there is a progressive de-watering of the shoreline. In Fig. 14 is shown the water at high and low points in the weekly fluctuation schedule. Now, since mosquito breeding occurs near the shoreline because of the fact that more vegetation and less wave action is found there, it can be seen that during the summer suitable breeding places for mosquitoes will be gradually and progressively destroyed. Vegetation which depends upon water for its survival will die, and debris or floatage will be stranded along the banks.

3) Predators. In nature there are always larger forms of life which prey upon the smaller forms, thus contributing to what is often called the "biological balance" in nature. Natural enemies of the anopheline larvae are the top minnows, aquatic bugs and beetles, dragonfly larvae, and many other forms of life.

(2) Chemical control of larvae--use of larvicides

At times it is impossible to effect biological control of mosquito propagation by any means at our disposal. In such instances it may be necessary to resort to the use of agents which will destroy the mosquito larvae. Such agents are called "larvicides." In general there are two types, namely, those which kill the larvae on contact and those which poison the larvae when eaten by them.

The larvicides which kill by contact are usually oily substances, one of the most effective of which is kerosene. When sprayed on the water surface (Fig. 15), they form a film and kill the larvae by closing their breathing tubes and poisoning the vital organs.

The most commonly used digestive poison is Paris green which is a compound containing arsenic. When larvae feed, they do not distinguish between substances which may form food for them or which are inert or poisonous materials. They simply swallow everything on the water surface small enough to get into their stomachs. If Paris green is dusted on the water (Fig. 16), it may be swallowed by the larvae, and the arsenic kills them. The usual procedure is to prepare a dust which is composed of from 15 to 25 parts of Paris green and

75 to 85 parts of some inert substance like powdered soapstone, hydrated lime, or road dust. This dust is usually distributed over the water through a small blower, either from a boat or, when larger areas of water surface must be treated, by means of airplanes.

There are many limitations to the use of larvicides as a malaria control measure. When a control program depends primarily on the use of larvicides, the larvicides must be applied to a given place at fixed intervals of about a week, for it must be remembered that the length of life of the mosquito in the larval state is about seven days. In the Tennessee Valley this means that larvicides must be applied for about 20 consecutive weeks, beginning about May 1.

Larvicides are expensive, both from the standpoint of cost of materials and cost of application. For instance, one pound of Paris green is used per acre per week for a period of about twenty weeks. The original cost of the Paris green plus the cost of mixing the larvicide, cost of diluent, labor, and application make the per treatment cost per acre in excess of 35 cents.

Aside from costs, larvicidal programs are incomplete as control measures. To be wholly effective, it would be necessary for the oil larvicide to reach every larva in a given place or for arsenic larvicides to be swallowed by each larva. It is practically impossible to accomplish this and, as a consequence, a certain number of mosquitoes nearly always manage to emerge from larvae which have not been destroyed by larvicides.

Theoretically, oil larvicides are better than dust larvicides. It is usually possible to get a more even distribution of the oil on the water surface and the oil will kill all stages of the mosquito larvae as well as the eggs and pupae. The larvae do not feed very much during the late fourth stage, just before changing into the pupae, and in the first stage, after the hatching of the eggs, they are so tiny that they may not be able to swallow particles of Paris green. Therefore, even with perfect distribution of dust larvicides, a certain number of larvae cannot be destroyed by this method.

It is clear that larvicidal work is of only temporary value and should be replaced wherever and whenever some more permanent method of control is found possible even though it might take several years to make the latter completely effective.

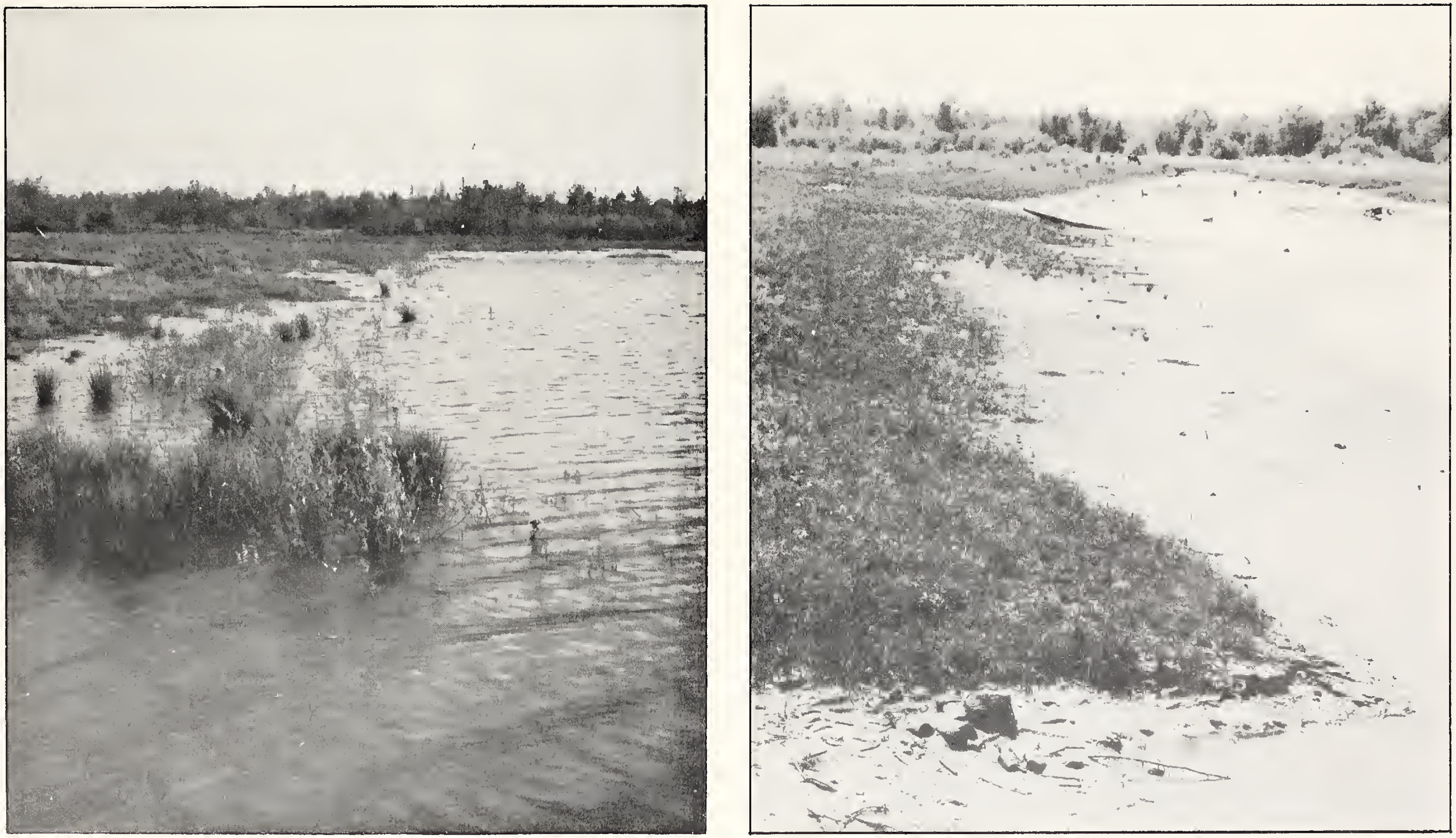


Fig. 14. Water at high and low points in the weekly fluctuation schedule.

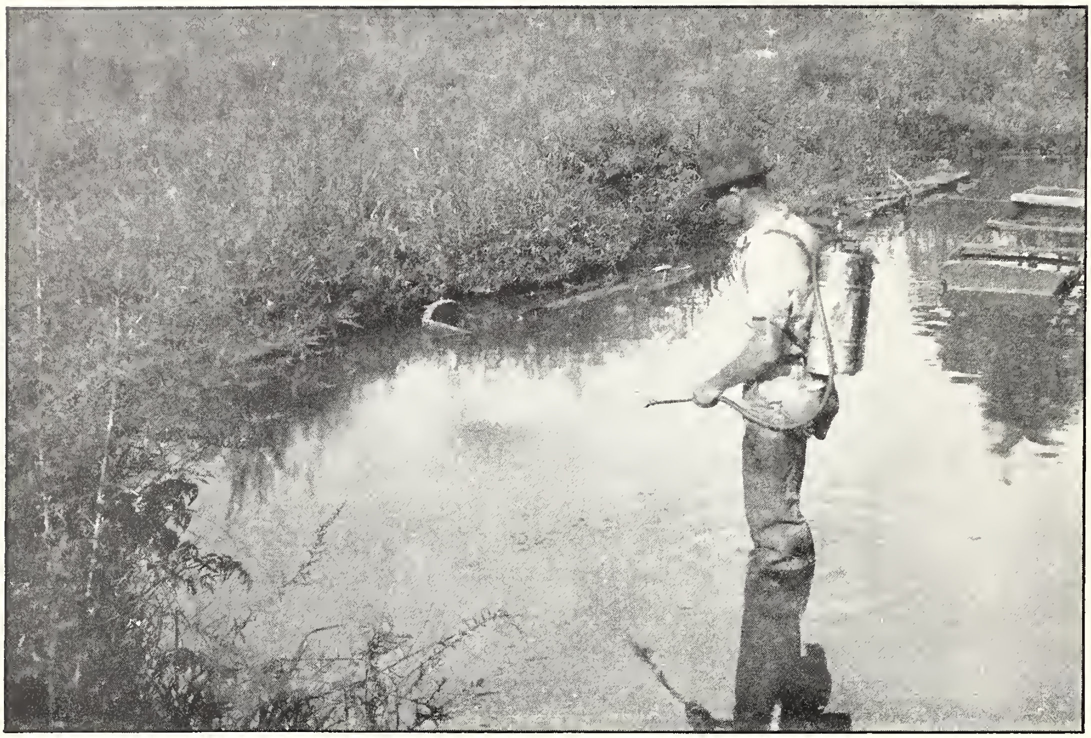


Fig. 15. Larvicides which kill by contact are usually oily substances. When sprayed on the water's surface, they form a film and kill the larvae.

Fig. 16. If Paris green is dusted on the water's surface, it may be swallowed by the larvae.

(3) Permanent control measures

Recently a new concept has been introduced into malaria control planning for the impoundments on the Tennessee River and its tributaries. This deals with the construction of permanent shoreline improvements such as dikes and levees and applies to those areas where the usual application of larvicides, annual growth removal, and marginal drainage maintenance will not control effectively and economically mosquito production because of size of the inundated area, flat topography, and limited scope of water-level fluctuation. These permanent improvements tend to reduce the cost and increase the effectiveness of specific control procedures after impoundage. In many instances, such work may eliminate entirely the necessity for continuing control while in others, maintenance and control operations will be necessary, but on a much reduced scale. In some instances it may be possible to "build" malaria out of a reservoir altogether.

Extensive studies of a reservoir to be impounded may indicate the feasibility of diking and de-watering certain areas. This is accomplished by constructing levees around flat areas and installing pumping equipment so that these areas may be de-watered during the mosquito breeding season. Diking and de-watering cannot always control all problem areas in a reservoir, however, and other measures must also be considered. These other measures include filling of shallow areas, restriction of land use within the one-mile zone to daytime occupancy, and such supplementary measures as mosquito proofing. In fact the filling of shallow areas is a method to be chosen over almost any other for areas for which it is suitable. This is true because there is little or no cost for future maintenance. Construction of low head dams near the upper end of the backwater and tributaries to provide for water-level fluctuation independent of the operation of the reservoir may also be recommended for certain areas as well as marginal drainage to prevent favorable breeding places when the water level is lowered.

From careful studies of the costs of a combined program of diking and de-watering, filling, restricted land use, mosquito-proofing and other permanent measures, it becomes evident that such a program can be justified by savings in annual costs alone, but the best reason for such work is the greater certainty of effective malaria control under a combined program. It is believed that under such a plan there is a possibility for gradual reduction in annual maintenance cost as against the likely cost increases should the usual program of larvicidal operations and shoreline maintenance be carried out.

Selection and Application of Malaria Control Measures

The selection and application of malaria control measures for a given situation depend upon a number of factors. These factors include the extent of Anopheles quadrimaculatus breeding and other conditions associated with the production of these mosquitoes. They include also the number of people within flight range of a breeding place, the agricultural practices of the people, and the amount of money which is available for malaria control. It is not often that a community in which malaria is prevalent can afford an elaborate control program. Adequate control of a single problem usually has to be undertaken with funds obtained in part from some source other than the people affected.

Most often, malaria control programs are established on a county-wide or even on a regional basis. This is as it should be, for in spite of the fact that malaria is always associated with the production of mosquitoes, this does not mean that all the malaria caused by a particular breeding place will occur within one mile of it. In these days of rapid transportation, it is possible for a person to become infected with malaria while visiting a place and not become sick with the disease until he has returned to his home somewhere else in the county or even in another state.

Migration of infected people has been shown to be responsible for outbreaks of malaria in places which had been free of the disease for many years. The mosquitoes had been there all the time but it happened that there was no malaria in the community for them to transmit to other people.

The first step in the selection of malaria control measures must be an accurate definition of the nature of the malaria problem requiring control. This includes a measurement of the amount of malaria in the community through malaria surveys. Next, it is necessary to know the location of breeding areas which might be the source of mosquitoes. Engineering estimates for the drainage of ponded water must be prepared on the basis of this knowledge.

After all of the various factors concerned in the production of the malaria problem have been assembled, then plans for control based on local conditions can be worked out. In the case of situations where drainage is impossible, where larvicidal programs are too expensive, and where only a few people are involved and the value of agricultural land is high, the use of mosquito-proofing may be the only means of control. Under similar conditions, but where agricultural lands are of little value, the removal of the people in the community beyond the possible influence of the mosquito-breeding places may be the most economical solution.

Whenever possible, complete drainage or eradication of the breeding places by filling should be done. In some instances partial drainage can be effected and this, combined with mosquito-proofing, may give a satisfactory degree of malaria control. As mentioned before, one of the important factors in determining the control measure to be applied is the amount of money available. Moreover, it is just as important to maintain control of malaria as it is to demonstrate that the disease can be prevented. It is necessary, therefore, to provide money for maintaining malaria control after it had once been established.

Malaria Control Measures in the Tennessee Valley

Until recent years, few organized control measures have been carried on in the Tennessee Valley region. Since 1934, however, the Alabama State Department of Public Health, with some assistance from the Tennessee Valley Authority, has been making a study of the Tennessee Valley in Alabama to determine the amount of malaria and the best methods for its control. While these studies are not yet complete, they have proceeded far enough so that a sound program of regional malaria control could be established if funds and community interest were sufficient to carry it out. Aside from the general studies on malaria and mosquito prevalence in the Valley, these investigations have included detailed engineering studies of all ponded water in the Alabama counties bordering the Tennessee River. Each pond, lake, and marsh has been investigated and classified according to its potentialities for mosquito breeding, and the location of each one has been spotted on county maps. It is not too much to say that, given community action and sufficient funds, it should be possible to eradicate malaria from most of the Tennessee Valley by carrying out plans which have been developed as a consequence of such studies.

In general, conditions producing malaria problems in the Tennessee Valley region are similar to those throughout the Southern States. Lime sink ponds and swampy lands are found, and temperature conditions are comparable. In one main respect only do the problems differ. In the Valley region certain sections of lake shores, created by the impoundments of the Tennessee River, add potential malaria hazards in a region sections of which were already suffering from malaria.

The Tennessee Valley Authority has assumed responsibility for controlling situations conducive to the breeding of malaria-transmitting mosquitoes along these impoundments, thereby protecting the people who live within mosquito flight range of its own reservoirs. In so doing, the Authority functions in the capacity of a land owner under the supervision of the health departments in the states in which its property lies. Measures employed are directed against the larvae of the mosquito and include drainage, where this measure is possible and practical; killing the larvae by means of Paris green and oils; and control through the checking of shoreline vegetation and through water level fluctuation.

In spite of the fact that observations on malaria have been proceeding for the past 2000 years, and a great deal of information of practical importance has been gained during the past 40 years, much more is needed. For this reason, malaria control on a regional basis should be related intimately to further investigations of the disease and of the mosquito which is responsible for its presence in a community. We should have more accurate information about the life history of the mosquito, since such information might give us additional facts about how the production of the mosquito could be controlled by biological means. It is known that certain ponds do not produce mosquitoes while others which look exactly like them do produce mosquitoes in great numbers. There must be a reason for this, but no one has found it. If a drug could be discovered, a dose of which would eradicate the malaria parasites in the human body and at the same time prevent any development of parasites introduced by the bite of a mosquito, a momentous step forward would have been achieved. The United States Public Health Service, State Health Departments, certain Foundations, and the Tennessee Valley Authority are all working on these problems and knowledge of malaria is slowly increasing.

But sufficient knowledge already exists, which if applied widely under competent direction, would go far toward the eradication of the disease in the Valley region. More nearly adequate funds are needed, and continuing intelligent support must be given by individuals and communities alike. When communities become fully aware of the seriousness of the disease and when they better understand the steps which are essential for the control of malaria, there is little doubt that both the community support and the money will be forthcoming. Upon these two factors depends success or failure.

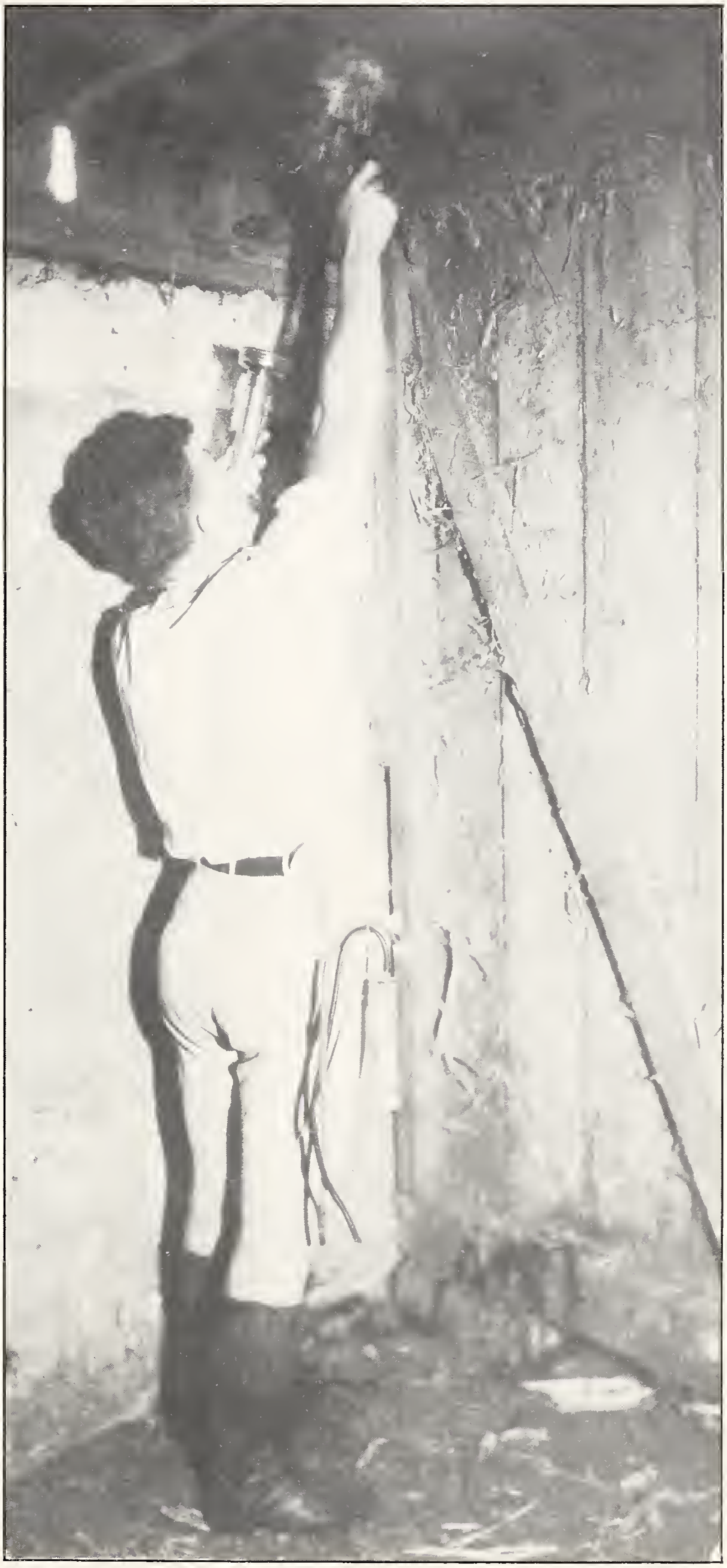


Fig. 17. Collecting Anopheles quadrimaculatus mosquitoes.

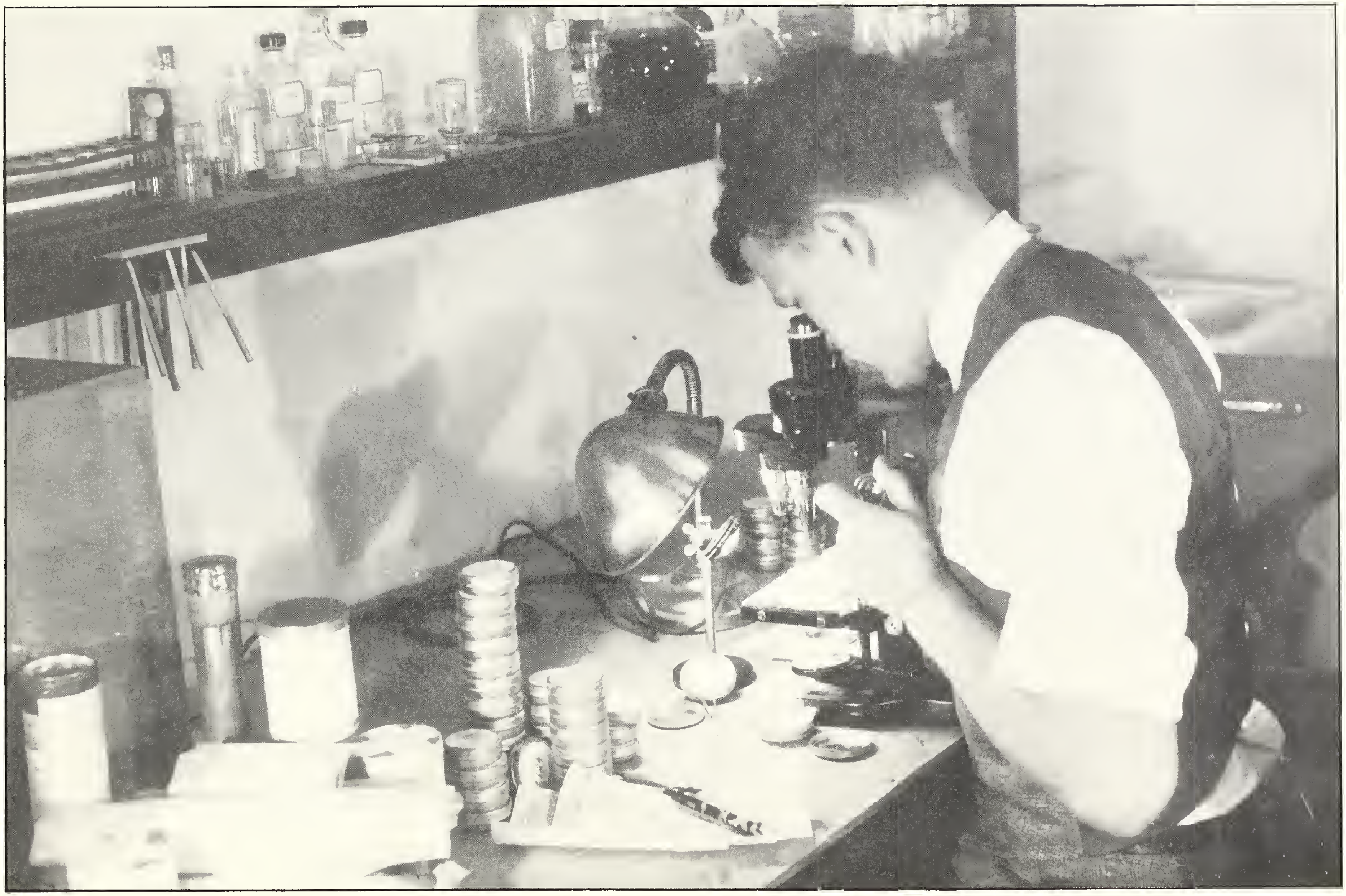


Fig. 18. Identifying mosquitoes which are brought into the laboratory.

SUPPLEMENTARY MATERIALS

A Guide to a Community Educational Program for Malaria Prevention and Control. Chattanooga, Tennessee: Health and Safety Department, Tennessee Valley Authority, 1941.

A Simple Plan for Screening the Farm Home. Washington, D. C.: Farm Security Administration, United States Department of Agriculture.

*Bishop, E. L. Consideration of the Malaria Problem in the Tennessee Valley in Southern Medical Journal, 30: 858-861, August 1937.

Breaking the Chain of Malaria Transmission. Photograph of an exhibit panel by the same name. Requests for a copy of this photograph should be addressed to: Health Education Services, Health and Safety Department, Tennessee Valley Authority, Chattanooga, Tennessee.

Carpenter, Stanley J. The Mosquitoes of Arkansas. Little Rock, Arkansas: Arkansas State Board of Health, 1939.

Carter, H. R. Malaria, Lessons on Its Cause and Prevention for use in Schools. Washington, D. C.: United States Public Health Service, 1936.

*Crowell, Robert L. Insectary Rearing of Anopheles Quadrimaculatus in American Journal of Hygiene, 32: 12-20, Sec. C, July 1940.

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*Hinman, E. Harold, and Hurlbut, H. S. A Study of Winter Activities and Hibernation of Anopheles Quadrimaculatus in the Tennessee Valley in American Journal of Tropical Medicine, 20: 431-466, May 1940.

Institute on Malaria Control. Nashville, Tennessee: State of Tennessee Department of Public Health, 1936. (In Tennessee counties with full-time health service, literature is available through the local health department; otherwise, literature is distributed directly from the central office in Nashville upon request. Outside of Tennessee, material is sent only to official agencies and organizations.)

Komp, W. H. W. A Guide to the Identification of the Common Mosquitoes of the Southeastern United States, Reprint No. 836 from The Public Health Reports, Washington, D. C.: United States Public Health Service, 1936.

Malaria. Montgomery, Alabama: Alabama State Department of Public Health, 1941. (This bulletin may be obtained without cost by residents of Alabama from their local county health department.)

Mayne, Bruce. Graphic Reproduction of the Life Cycle of the Malaria Parasite in the Mosquito Host, National Institute of Health Bulletin No. 170. Washington, D. C.: United States Public Health Service, 1938.

Mosquitoes. Richmond, Virginia: Virginia State Department of Health. (Single requests can be filled without difficulty.)

Repair of Wire Screening (chart). Washington, D. C.: Farm Security Administration, United States Department of Agriculture.

Some Facts Concerning Malaria. Raleigh, North Carolina: North Carolina State Board of Health. (In limited quantities no charge is made for this material.)

The Screening and Mosquito-Proofing of Houses. (This is a reprint of a bulletin prepared by Dr. C. P. Coogle of the United States Public Health Service.) Available from Alabama State Department of Public Health, Montgomery, Alabama.

*Watson, Robert Briggs, and Bishop, E. L. Control of Anopheles Quadrimaculatus in the Tennessee Valley in Proceedings of the 27th Annual Meeting of the New Jersey Mosquito Extermination Association, March 1940.

*Watson, Robert Briggs, and Spain, E. L., Jr. Studies on Malaria in the Tennessee Valley, the Influence of Physiography on the Occurrences of Breeding Places of Anopheles Quadrimaculatus in Northern Alabama in American Journal of Tropical Medicine, 17: 289-305, March 1937.

Malaria, The Story of An Individual Problem and a Community Problem. Chattanooga, Tennessee: Health and Safety Department, Tennessee Valley Authority, 1941.

Malaria in Our Community. Chattanooga, Tennessee: Health and Safety Department, Tennessee Valley Authority, 1941.

Other materials not for general distribution, such as radio talks and exhibits, may be available through local or state departments of health.

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*A limited number of reprints are available upon special request. Please direct inquiries to: Health and Safety Department, Tennessee Valley Authority, Chattanooga, Tennessee.